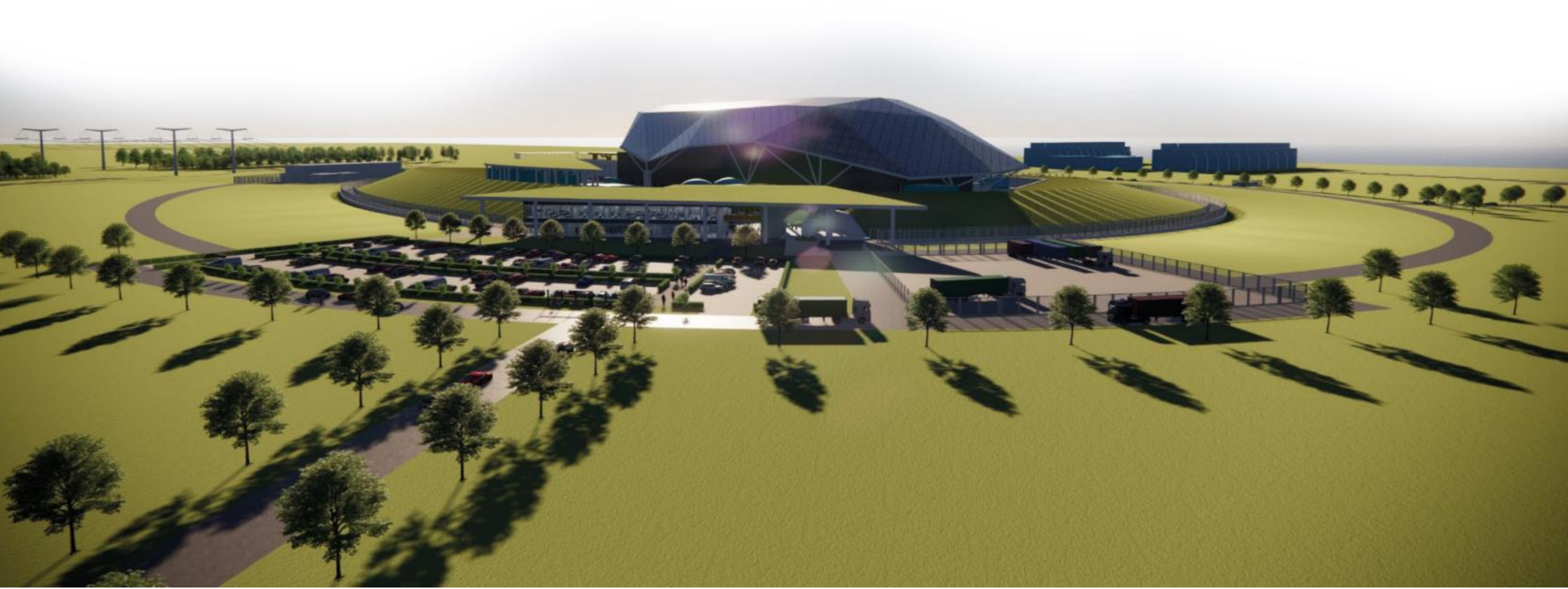
Environment, Safety, Security and Safeguards Case Version 2, Tier 1, Chapter 27: Demonstration of Best Available Techniques



Record of Change

Date	Revision Number	Status	Reason for Change
29/2/2024	1	Issue	First issue of Chapter 27 which reflects Reference Design 7 and is aligned to Design Reference Point 1.
May 2024	2	Issue	Updated to correct revision history at issue 1. Chapter changes include: • Additional detail within conclusions section for how arguments and evidence presented meet the generic E3S Case objective • Chapter number added to top level claims for consistency with other E3S Case chapters • Minor changes to Figure 27-5-3 (metal melting added) and Figure 27-6-2 (third column minor amendment to argument including adding reference to claim 2) Minor template/editorial updates for overall E3S Case consistency.

Executive Summary

Chapter 27 of the Environment, Safety, Security and Safeguards (E3S) Case for the Rolls-Royce Small Modular Reactor (RR SMR) summarises the demonstration of best available techniques (BAT) for the RR SMR and follows the Claims, Arguments and Evidence (CAE) model.

The CAE model provides a transparent framework for the demonstration of BAT in the design of the RR SMR. The CAE model is well-established in the United Kingdom (UK) and is routinely used in the development of safety cases for nuclear facilities.

The BAT methodology detailed in the Approach for Optimisation through the Application of BAT [1] report has been followed to ensure BAT is applied throughout the design process. The methodology is summarised within this chapter.

This issue of chapter 27 provides an outline of progress made towards the demonstration of BAT, based on the design of the RR SMR at Reference Design 7 (RD7), aligned to design reference point 1 (DRP1), and highlights the forward actions (FA) which will be undertaken to fully achieve the objectives for the mature RR SMR design.

The chapter provides an overview of the BAT claims and subclaims identified at RD7/DRP1 and provides a summary of the potential arguments and evidence that will support and demonstrate that the RR SMR can meet the BAT claims.

Contents

Tables

Figures

27.0 Introduction to Chapter

27.0.1 Introduction

Chapter 27 of the Rolls-Royce Small Modular Reactor (RR SMR) generic Environment, Safety, Security and Safeguards (E3S) Case presents the demonstration of best available techniques (BAT) for the RR SMR.

The demonstration of BAT is based upon consideration of applicable relevant good practice (RGP), regulatory requirements and associated guidance. BAT for the RR SMR has been developed using the methodology described in the report "Approach for Optimisation through the Application of BAT" [1] referred to throughout this chapter as the 'BAT methodology'. A key feature of the adopted methodology is the integration of BAT into the engineering design process, alongside safety and security principles to achieve holistic optimisation of the RR SMR power station.

This chapter should be read in conjunction with the BAT methodology [1] which is a publicly available document and is part of the overall E3S Case. The methodology has been summarised within this chapter.

This chapter provides the initial BAT case for the RR SMR and seeks to demonstrate that the design has been optimised and "uses BAT to prevent or minimise harm to people and the environment" from the use, generation, discharge, and disposal of radioactive substances and waste arising over the lifecycle of the RR SMR.

While the RR SMR is a first of a kind (FOAK) design, it is an adaptation of existing pressurised water reactor (PWR) technology, and meaningful feedback and operational experience (OPEX) has consequently been obtained from existing PWR power station designs. The demonstration of BAT thus considers the evolution of the RR SMR from standard PWR designs and a description of the improvements in environmental performance, to support the arguments that the RR SMR applies BAT.

Recognising that BAT will change over time (on account of changes in legislation, scientific and technological advances, and the natural evolution over the lifecycle of the design), care has been taken in identifying BAT for the RR SMR so as not to prejudice viable options that may become available to future operators or foreclose their consideration of suitable alternatives.

This chapter will be updated as the design of the RR SMR matures, to demonstrate that BAT continues to be applied and to ultimately justify that RR SMR has been optimised and impact on waste and discharges reduced to levels that are as low as reasonably achievable (ALARA).

27.0.2 Scope and Maturity

This chapter addresses BAT as it applies to all RR SMR physical structures, systems, and components (SSCs). All SSCs within the RR SMR are to a lesser or greater extent subject to BAT considerations. Application of BAT will be considered for all SSCs as a requirement of the design process. However, a proportionate approach for this chapter is to focus on:

- Those aspects of the design that have the highest impact on people and the environment
- Those aspects of the design that are different for the RR SMR (from other PWR plants)

- Demonstrating that the RR SMR can meet the radiological BAT claims.

This chapter will predominantly cover the SSCs that contain or could potentially contain radioactive substances in normal operations. Therefore, Reactor Island (RI) SSCs and associated processes under normal operations, maintenance activities and expected events will essentially form significant components of this chapter. BAT will also support the definition of environmental protection functions (EPF) for RR SMR's SSCs [2].

BAT applies to all phases in the RR SMR product lifecycle. While the principal focus is on the design phase, due consideration is given to potential impacts of design options during the operating and decommissioning phases. This ensures that BAT solutions with evident short-term benefits do not present intractable challenges in the long term.

The underlying philosophies, principles, and the resulting holistic optimisation process which has been applied to the RR SMR throughout the design process are described in detail in the BAT methodology [1]. A summary of the optimisation process is provided within section 27.1.

At Version 2 of the generic E3S Case, as the design matures towards a final concept definition (FCD), the E3S design principles are well established and the approaches to support the RR SMR design and E3S analysis are adopted in the design development process. The conclusions of this chapter provide a forward look of information still to be developed for chapter 27 to achieve the generic E3S Case objective.

27.0.3 Claims, Arguments and Evidence Route Map

The overall approach to claims, arguments and evidence (CAE) and the set of fundamental E3S claims to achieve the E3S fundamental objective are described in E3S Case, Version 2, Tier 1, Chapter 1: Introduction [3].

In broad terms:

- A claim is a statement or an assertion of truth. In BAT terms, it is a statement of what will be achieved, and often relates to compliance with regulatory requirements or a high-level RR SMR E3S goal covering E3S Principles. A sub-claim is a logical decomposition of a claim.

- An argument is a reason or set of reasons presented in support of an idea or to demonstrate a truth. In BAT terms, it refers to justifications or statements presented to validate a claim, and typically involves identification of design features that support a claim.

- Evidence is a body of facts or information presented to support or validate an argument. In relation to BAT, evidence comprises all information provided to demonstrate the application of BAT and underpin arguments made. Evidence should be presented to a sufficient level of detail to allow scrutiny and should be accompanied by an assessment of gaps/uncertainties in data.

The associated top-level claim for E3S Case, Version 2, Tier 1, Chapter 27: Demonstration of BAT is:

Claim 27: The RR SMR has been optimised through the application of BAT to prevent or, where not practicable, minimise the generation of radioactive wastes and discharges, to minimise the impacts on the environment and members of the public.

This top-level claim is decomposed into several high-level (level 1) radiological claims, which will need to be supported by suitable arguments and evidence to show that the design of the RR SMR has been optimised and can meet the E3S fundamental objective.

- **Claim 27.1:** The design of the RR SMR eliminates or reduces the generation of radioactive wastes and spent fuel (SF)
- **Claim 27.2**: The design of the RR SMR minimises the volume and/or activity of aqueous and gaseous radioactive effluent discharged to the environment
    - **Claim 27.2a**: The leakage of primary and secondary coolant is minimised
    - **Claim 27.2b**: The discharge of gaseous radioactive wastes to the environment is minimised
    - **Claim 27.2c**: The discharge of aqueous radioactive wastes to the environment is minimised
- **Claim 27.3**: The design of the RR SMR minimises the volume and activity of radioactive solid and non-aqueous waste disposed of to other premises
- **Claim 27.4:** The design of the RR SMR minimises the impacts on the environment and members of the public
    - **Claim 27.4a**: Radioactive waste (aqueous and gaseous) discharge routes and structures are optimised
    - **Claim 27.4b**: Final disposal routes for solid, non-aqueous radioactive wastes and Spent Fuel are optimised.

A decomposition of these high-level claims into sub-claims, and mapping to the relevant Tier 2 and Tier 3 information is presented in the E3S Case Route Map [4] and within sections 27.3 to 27.6 of this chapter. Given the evolving nature of the E3S Case alongside the maturing design, the underpinning arguments and evidence will continue to be developed in future design stages.

For Version 3 of the E3S Case, a dedicated report for each of the four high-level claims above will be produced to provide detailed demonstration of BAT to support this chapter. These reports will be made publicly available.

A summary of the arguments and evidence from lower tier information, available at RD7/DRP1 is presented within sections 27.3 to 27.6 of this chapter.

27.0.4 Applicable Regulations, Codes and Standards

Section 2 of the BAT methodology [1] provides detailed information on the regulatory framework applicable for BAT.

Figure 27.0-1 below provides an overview of key regulatory framework and RGP that apply to BAT. Figure 27.0-1 also shows how regulatory framework influenced the development of the RR SMR E3S principles and BAT methodology. Section 27.1 of this chapter provides more information on how E3S principles are incorporated into the BAT methodology and the design of the RR SMR.

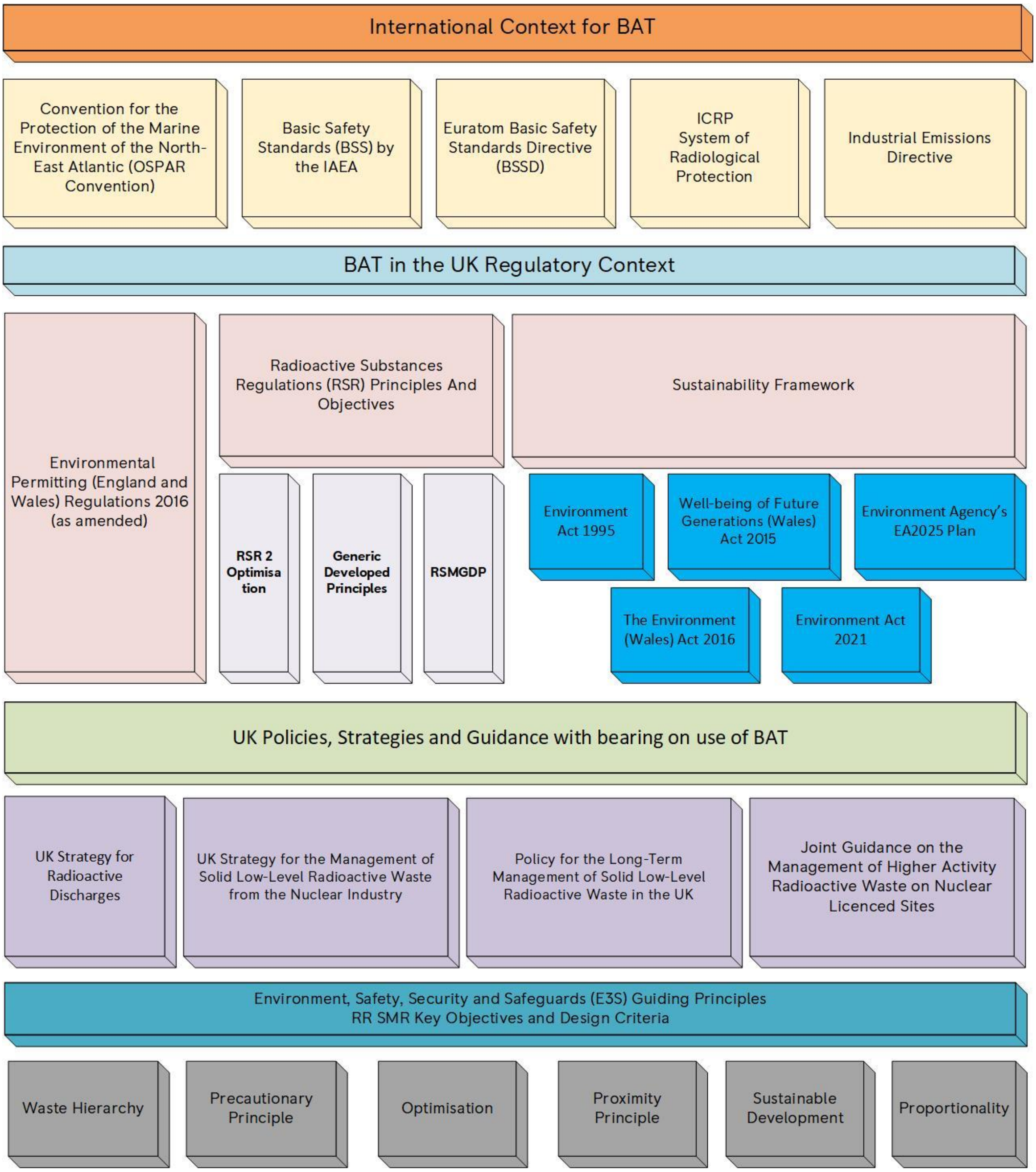


Figure 27.0-1 Overview of regulatory framework and RGP relevant to BAT used to develop RR SMR E3S principles

27.1 Best Available Techniques Methodology

27.1.1 Approach for Optimisation through the Application of Best Available Techniques

A key objective of the RR SMR is to ensure adequate protection of people and the environment from harm at all lifecycle phases of the power station [3]. This objective is consistent with the fundamental principle of reducing impacts to levels that are ALARA using BAT.

The Approach for Optimisation through the application of BAT [1] details the methodology adopted by Rolls-Royce SMR to demonstrate that the environmental performance of the RR SMR has been optimised, and that the potential impacts on people and the environment predicted to arise from the operation of the RR SMR have been minimised. A high-level summary of the methodology is provided here.

The methodology for gathering and evaluating BAT is aligned with, and fully integrated, into the engineering design process 'C3.3.3-2 Conduct design optioneering' [5]:

- E3S principles have been developed from legislative requirements and RGP and are used to support development of requirements and other design inputs that SSCs must comply with.

- The BAT claims that must be demonstrated for the RR SMR are based upon the E3S principles.

- Options which can meet the design requirements are then generated and evaluated, taking into consideration RGP and OPEX (across all areas).

- The RR SMR key design principles and assessment criteria used to evaluate options during design, have been developed to meet the E3S principles and explicitly incorporate criteria on environment, safety, safeguards and security alongside technical feasibility, cost, and market factors.

Integration of the BAT methodology into the engineering conduct design optioneering process for the RR SMR allows a holistic consideration and optimisation of all the key factors influencing design decisions and provides confidence that the final design solutions will demonstrate BAT, as low as reasonably practicable (ALARP), Safeguards by Design and Secure by Design at a fundamental level from the outset. The demonstration of all these elements will also provide evidence that the RR SMR will also be Sustainable by Design.

Section 3 of the BAT methodology describes how the E3S principles and the key design objectives and assessment Criteria for the RR SMR have been developed from legislative requirements and RGP [1]. The BAT methodology also describes how Rolls-Royce SMR Limited has adopted a requirements-led approach for the RR SMR power station development programme.

The approach is used to establish a clear definition of the design requirements for all SSCs within the RR SMR. The framework allows the decomposition and flow-down of requirements from higher to lower level SSCs to ensure that optimised design solutions are developed at every level, whilst maintaining traceability back to the original requirement.

The design process begins with the definition of requirements, arising from identification of a problem or opportunity, or from existing stakeholder requirements. Requirements management is a vital first step in the design process. It is used to build an agreed understanding of the design problem, which forms the basis for all future design activity. Figure 27.1-1 provides a simplified overview of how E3S principles, BAT claims and requirements are integrated into the conduct design optioneering process. This figure is not exhaustive, other factors such as build risk and costs also feed into the conduct design optioneering; these are not reflected in Figure 27.1-1. Further details can be found in E3S Case Development and Management Arrangements [6].

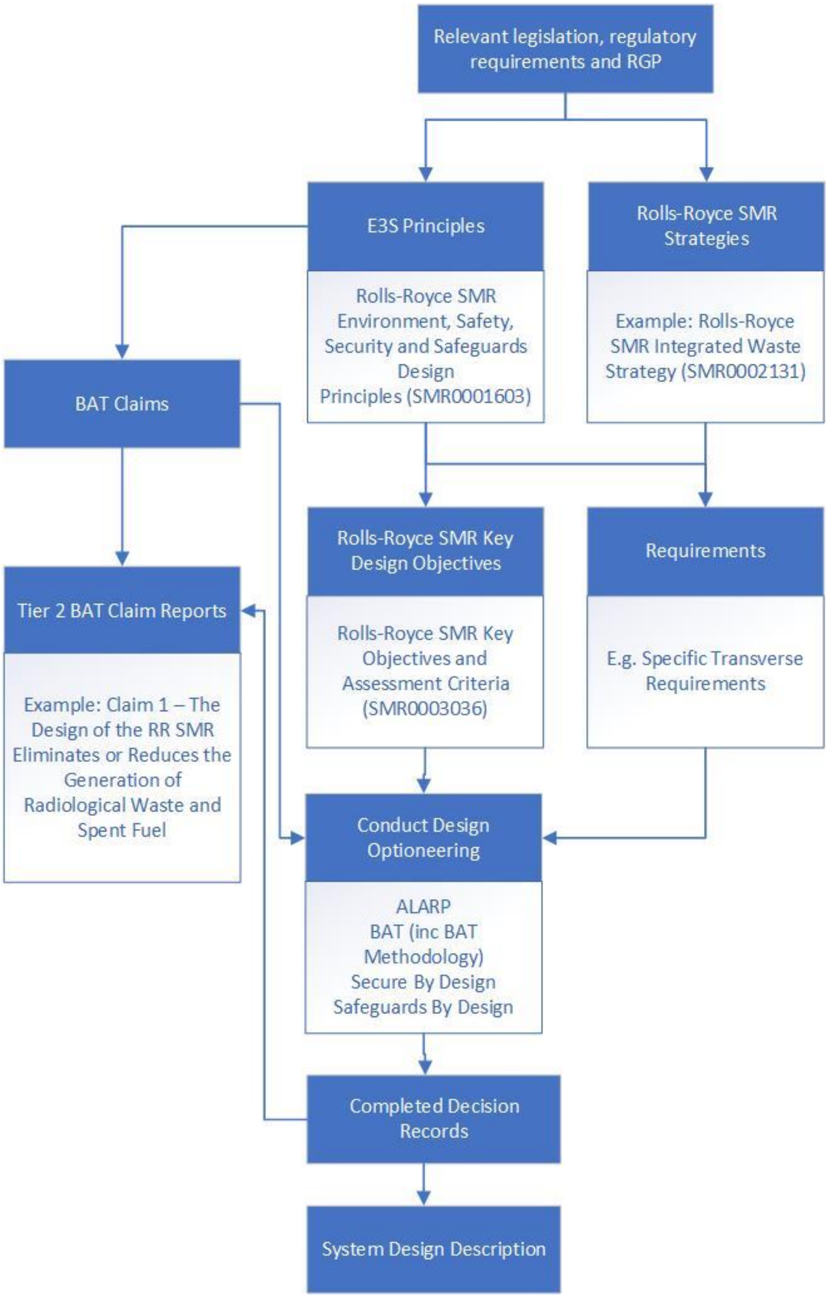


Figure 27.1-1 Overview of how RGP / Legislation is incorporated into BAT and Engineering Design Processes

Generation of design concepts and identification of the preferred design solution to fulfil defined requirements is achieved through the structured conduct design optioneering process [5].

The conduct design optioneering and decision-making process effectively constitutes the methodology for identifying and applying BAT in the design of the RR SMR. The conduct design optioneering and all associated documents are all captured within the Rolls-Royce SMR integrated management system (IMS). The IMS provides further detailed information on processes alongside tools and guidance to support design engineers.

The design optioneering process ensures that:

- The scope, boundaries, assumptions, limitations (constraints) and associated uncertainties of the problem/opportunity/requirement triggering the design activity are recorded and well understood.
- Relevant stakeholders are identified and involved in the process.
- RGP and OPEX are identified and considered when generating options.
- There is traceability in the decision-making process and decisions are justified.
- Decisions are formally approved and recorded (via the Decision Record template TS DD 02) [7], the completed document will be a key piece of evidence in the demonstration of BAT.

The main elements of the conduct design optioneering process, are described in detail within the BAT methodology, and have been adapted into a simplified, descriptive summary presented in Figure 27.1-2. The Decision Record template has a section for each of the steps identified in Figure 27.1-2.

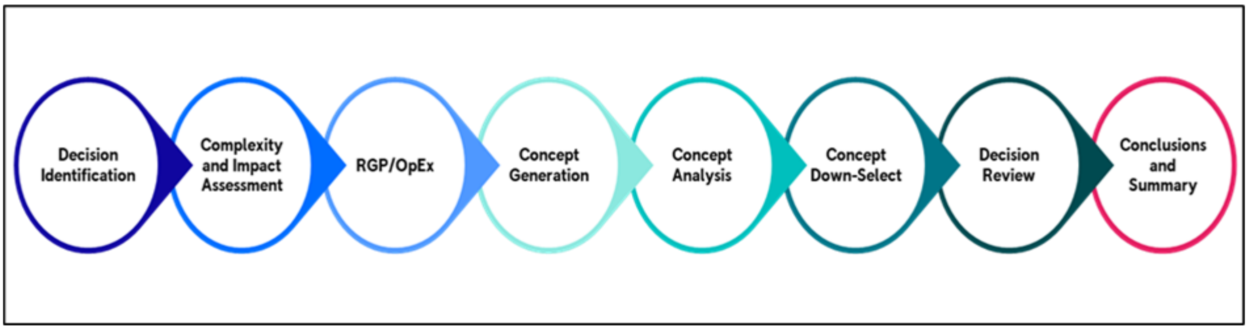


Figure 27.1-2 RR SMR Simplified Conduct Design Optioneering and Decision Process

Table 27.1-1 describes the steps in the design optioneering (BAT) process and the aligned sections in the decision record template (represented in Figure 27.1-2) and shows how they relate to the conduct design optioneering steps. Figure 27.1-2 was generated specifically for training purposes to explain each of the different sections in the decision record template which are aligned to the design optioneering steps. It complements the design optioneering process, essentially breaking down the conduct design optioneering process steps further and emphasises elements of the decision record template that are particularly applicable / required for BAT.

Table 27.1-1 Summary of Design Optioneering Steps and Corresponding Decision Record Template Sections

Conduct Design Process Step	Decision Record Process Step	Description
Step 1: Understand the problem	Decision Identification	Decision context description. Decision level (who's responsible for signing-off). Clear definition of the scope and boundaries of the design decision. Identification of limitations or constraints. List of relevant assumptions with their Dynamic Object Oriented Requirements (DOORs) database reference. Decision level – 1 (major design decision requiring senior management sign off) to 5 (minimal impact, engineer sign off). BAT methodology provides detail on levels. IMS states expectations of signatories and provides steps that need to be carried out prior to signing off a decision. Defines the function(s) that a design optioneering fulfils and the purpose of the SSCs that deliver the function. Identification of relevant stakeholders.
	Complexity & impact assessment	Determines optioneering/depth of analysis required. Determines which stakeholders need to be consulted and at which stage. Record of stakeholders - formal technical review (TR) sign the completed decision record. Otherwise, names recorded in minutes of meetings. (BAT methodology - Section 4 in [1])
Step 2: Create decision ID	Step not identified	Administrative step but ensures all decisions have unique number for traceability.
Step 3: Generate concepts	Review of RGP/ OPEX	Review of established RGP and OPEX in delivering the functions and purposes/requirements identified in Step 1. Supports the generation of options to be evaluated.
	Concept generation	Functional means assessment (FMA) is used to identify options that meet the functional requirements. Options that are not viable or are demonstrably inferior to other options are eliminated, and feasible options are taken forward for detailed assessment in the next step.
	Concept analysis	Provide detailed description of the design concepts/options identified in the previous step. Any uncertainties in information, data are captured.

Conduct Design Process Step	Decision Record Process Step	Description
Step 4: Assess concepts	Concept down-selection	Coarse screening (if required) to reduce identified concepts for detailed evaluation.
	Decision Review	Detailed evaluation of options: Strengths and limitations for each option are evaluated in turn for different attributes, aligned with the RR SMR key assessment and design criteria (including safety, security, environmental protection, cost, schedule, and programme). Identifies the key points that may be used to discriminate between the options. Constraints or limitations are reflected in the scoring, Uncertainties associated with the design captured such as insufficient design definition.
Step 5: Formalise / review decision	Conclusions and Summary	Decision analysis and conclusion – supports selection of the BAT (ALARP / Secure by Design) option (evidence for BAT case). Any further work that needs to be considered in future design phases should be captured (and re-evaluated) following its completion. Constraints, additional analysis, design work or other decisions that need to mature are identified. Further work to resolve foundational assumptions is noted.
Step 6/7 Log decision and update programme	Step not identified	Administrative step - all relevant documentation is updated to ensure that 'decision' is captured throughout the programme, for example assumptions in DOORS.

BAT, in simplistic terms, can be considered in two stages:

- Optioneering – which focuses on ensuring that the right 'strategic' option is chosen when looking at the overall impacts.
- Optimisation - need to consider how to implement (and potentially improve on) the chosen option to ensure it is executed in the best way to minimise impact on the environment, health, safety and other decision criteria.

Application and demonstration of BAT is a continuous and ongoing process that continues over the lifetime and each phase of a project. The focus of the current RR SMR BAT methodology reflects the optioneering required in the early design stages of a project. The BAT methodology will be updated as the design matures, and optimisation becomes the focus. Further detail on optioneering, optimisation and how it relates to the design stages of the RR SMR are detailed within section 4.3 of the BAT methodology [1].

27.2 Demonstrating the Application of Best Available Techniques

27.2.1 Claims–Arguments-Evidence Approach

The demonstration of BAT for the RR SMR has followed the CAE model. This model provides a systematic, evidence-based approach for substantiating claims made regarding the safety and environmental performance of plants, systems, and components. It provides a transparent framework for the demonstration of BAT in the design of the RR SMR. The model is well-established in the UK and is routinely used in the development of safety cases for nuclear facilities. A description of the terms is provided in section 27.0.3.

Use of the CAE approach to demonstrate BAT has been successfully applied in previous nuclear power plant (NPP) safety case submissions and is considered by the Environment Agency (EA) to provide a suitable basis for the identification of BAT [8]. High-level claims on the application of BAT in the design of the RR SMR, have been derived from United Kingdom (UK) regulatory precepts and established RGP [9] [10] [11].

It is noted that the CAE model does not always follow a linear approach. In practice, existing evidence may be used to develop arguments. Analysis of gaps and uncertainties in the arguments may then prompt further gathering of evidence to consolidate the arguments and evidence base, in an iterative manner until a sufficient level of evidence is attained.

27.2.1.1 Claims - Arguments - Evidence Structure

A top-level claim for the chapter and a set of four high-level claims, outlined in section 27.0.3, covering radiological environmental aspects and impacts, have been established to support the demonstration of BAT for the RR SMR. These claims have primarily been based on the RR SMR's key objectives and assessment criteria [12], regulatory requirements set out in Environmental Permitting (England and Wales) Regulations 2016 (EPR16) (as amended) (particularly Schedules 7, 8 and 23) [11] and associated regulatory guidance and RGP [9] [10].

Claims for non-radiological or conventional aspects have also been developed. These claims also incorporate sustainability objectives based on sustainable development principles, with emphasis on the environment protection aspects. Whilst a demonstration against these claims will be provided for the final generic E3S Case the focus of this chapter is on radiological claims only. It is noted that the socio-economic and governance aspects of sustainable development are addressed in the wider Rolls-Royce SMR sustainability policy [13].

Development of the CAE framework for the RR SMR BAT case is ongoing and the framework, and the body of evidence will continue to be developed and refined in an iterative manner as the design of relevant SSCs matures. The claims and decomposition of claims, argument headings and the actual arguments and evidence will therefore change as the design matures.

The following sections 27.3 to 27.6 will for each high-level claim (level 1) provide a summary of how the claim is broken down into sub-claims (where applicable), the argument heading and an indication of how the argument(s) are progressing, identifying key documents that provide the supporting evidence.

The BAT claims are applicable to all the lifecycle phases of the RR SMR (from the current design phase to the decommissioning phase), although the emphasis will differ during different phases of the lifecycle. The claims will be substantiated by reasoned arguments, supported by robust evidence showing the evolution of the RR SMR design, and the improvements in environmental performance achieved.

The RR SMR BAT case is prepared by a team of competent persons, under the leadership of the BAT case lead. The case production commences with the development of a BAT case framework, based upon the fundamental claims listed earlier. Each claim is decomposed into a set of sub-claims (as appropriate) and reasoned arguments are advanced to underpin each claim or sub-claim.

In parallel, a systematic review of SSCs included in the generic design assessment (GDA) boundary document [14] (including the scoping and submission plans for relevant chapters of the E3S Case) is performed by the BAT case team, and SSCs delivering requirements associated with the identified claims and sub-claims are established. The decision records for SSCs which include a BAT justification, alongside other engineering documents such as system design descriptions (SDDs) are used as evidence to substantiate the arguments presented for each claim. To enhance the design optimisation process, the BAT case team will engage with design engineers and the design integration engineers throughout the process to ensure that documents provide the required level of detail and justification.

A clear and logical CAE structure is then documented for each fundamental claim and aggregated into the BAT case. The BAT case is then subjected to technical, assurance and independent peer reviews, and subjected to the document control and approval processes.

The BAT case will be updated periodically to reflect growing design maturity of the RR SMR. The case is also expected to undergo periodic updates during all phases of the RR SMR lifecycle, to reflect design changes that may be instigated by operator choices and the evolution of the power station (over its operating and decommissioning lifecycle phases).

The overall BAT case will be summarised in chapter 27. For each high-level BAT claim identified in section 27.0.3 a technical report will be produced which will provide the detailed arguments needed to demonstrate that the RR SMR can meet the claim and identify the underpinning evidence.

FA 27.1: Continue to develop arguments and evidence to demonstrate that the RR SMR can meet BAT claims and produce technical report for each claim.

27.3 Demonstration of Claim 27.1

27.3.1 Summary of Demonstration for Claim 27.1

Figure 27.3-1 to Figure 27.3-5 show the decomposition of claim 1 and provides the current argument headings, summarises the arguments, and identifies the key evidence that supports the demonstration that the design of the RR SMR can meet Claim 27.1: The design of the RR SMR eliminates or reduces the generation of radioactive waste and spent fuel (SF). The summaries provided in this chapter will be supported in future issues by detailed technical reports for each high-level claim.

The majority of SSCs are still in the early design stages and have not yet reached the design stage at which the final strategic option has been selected. Therefore, the arguments and evidence provided in Figure 27.3-1 to Figure 27.3-5 are not comprehensive, further work and development is required to fully demonstrate BAT for claim 27.1.

For this version, the summary figures provide an indication of how the argument(s) are progressing and identify key documents (references) that are available as supporting evidence. For certain arguments there may be limited or no current evidence, where possible the illustrative argument based on RGP/OPEX is provided.

The RR SMR elements that are considered particularly important for claim 27.1 are:

- Design measures to ensure fuel integrity
- Specification of materials to reduce potential for activation and corrosion, for example zirconium alloy fuel cladding which is resistant to corrosion
- Design of the fuel core and operating strategy of the reactor including fuel positioning and cycle length to minimise generation of mobile radioactivity
- Provision of measures such as the heavy reflector to minimise neutron leakage
- Boron free chemistry.

Claims	Claim 27.1: The Design of the RR SMR Eliminates or Reduces the Generation of Radioactive Wastes and Spent Fuel (SF)		
	Sub-Claim 1-1A: The RR SMR Fuel is Designed, Manufactured & Managed to Minimise the Generation of Radioactive Wastes and SF		
Argument Summary	C1-1Aa: The RR SMR fuel is designed to minimise release of fission products into the primary coolant.	C1-1Ab: The fuel manufacturing process eliminates or reduces the generation of radioactive wastes.	C1-1Ac: Fuel handling and storage arrangements minimise the generation of radioactive wastes and SF.
	The design of the RR SMR fuel considers a number of measures to enhance the physical integrity of fuel rods and assemblies to minimise the potential for pin failure. This in turn minimises the release of radionuclides into the primary coolant, with eventual releases to the environment, and the generation of radioactive waste in the coolant treatment systems including: - Choosing fuel cladding material such as zirconium-based alloy based on corrosion resistance, irradiation growth and permeability to fission and activation products to ensure fuel integrity and retain fission and activation products within the fuel pin. - Fuel design to limit physical damage due to mechanical wear, impact and corrosion. The integrity of the RR SMR fuel will be ensured by fuel vendors through fuel design, fabrication, testing and inspection. Design development of the RR SMR fuel is ongoing, it is anticipated that the final fuel concepts will be based on modified versions of existing designs. Arguments(s) will need to identify and justify all design features aimed at tackling the mechanisms that accelerate pin failure	Fuel cladding defects, and uranium contamination on the surface of fuel elements (tramp uranium) can both result in the release of fission products into the primary coolant during operation which must then be removed, resulting in the generation of waste. The likelihood of releases via these mechanisms is minimised through high standards of fuel manufacture together with inspection, testing and cleaning. RR SMR are under contract with a "fuel vendor". We are using their fuel design / substantiation etc to help set limits on the core design. Discussions are ongoing. Fuel vendors will need to demonstrate that they have robust manufacturing processes to prevent defects that could impact fuel integrity	Fuel handling equipment and arrangements can minimise the potential for damage to fuel and spent fuel during transportation, loading, unloading and storage. The RR SMR mechanical handling systems are designed to minimise the potential for damage to both fresh and spent fuel during handling and transfer. Spent fuel unloaded from the RR SMR core will be temporarily stored in the Spent Fuel Pool (SFP) [FAB10] for cooling. The conditions of the SFP are carefully controlled to maintain the integrity of the fuel cladding and prevent the release of fission products. Further information is provided in C3a-1Ab. Following cooling in the SFP [FAB10], proposed dry interim storage of spent RR SMR fuel (in casks) in [FDB], will eliminate the generation of liquid, gaseous and solid radioactive wastes associated with the operation and decommissioning of wet storage systems.
Evidence	Examples of Evidence: • SMR0005138_1: RR SMR Core Design Description • SMR0004523 Core Design Iteration 6 • SMR0004986_1: Reactor Systems Design Description • SMR0004210_2: E3S Case Chapter 4: Reactor (Fuel & Core) • SMR0000594_1:RR SMR Design Overview Report	Examples of Evidence • E3S Case Chapter 4 Reactor (Fuel & Core) • EDNS01000371047_3: UK SMR Design Summary • SMR0009502 HE-UFC Qualification Basis for PWRs	Examples of Evidence • System Outline Description for Handling of Nuclear Equipment [F] System SMR0000983_002 • SMR0006314_002: SDD for Fuel Transfer System [FCK] • SMR0004780_002: SDD for the Refuelling Cavity [FAE] System • SMR0004779_002: SDD for the Refuelling Pool [FAF] System

Figure 27.3-1 Summary of Claim 27.1, Sub-Claim 1-1A

Claims	Claim 27.1: The Design of the RR SMR Eliminates or Reduces the Generation of Radioactive Wastes and Spent Fuel (SF)	
	Sub-Claim 1-2A Efficient Use of Fuel to Reduce the Generation of Radioactive Waste(s)	
Argument Summary	C1-2Aa Design of the RR SMR Reactor Core maximises power generation efficiency and minimises generation of mobile radioactivity	C1-2Ab: Optimisation of Fuel Enrichment, Fuel Burn-up and Fuel Cycle to reduce the generation of radioactive wastes.
	The reactor core design can optimise the energetic efficiency by maximising the efficient use of the neutrons produced, and thereby maximising the heat output per unit of fuel. For a given thermal output, this minimises both the consumption of uranium and the radioactive waste arisings in the form of spent fuel. Design features to support this sub-claim include: - reactor core configuration, fuel loading patterns and the types and positioning of control rods - use of heavy neutron reflector to improve neutron economy and reduce neutron leakage, improve burnup of peripheral fuel and reduce Reactor Pressure Vessel (RPV) damage, - a water moderator ensures the so called 'mean-free-path' of a neutron is only 1-2 cm. - use of irradiation embrittlement resistant material for RPV forging and corrosion resistant material for pipework *Further information on fuel efficiency is presented in 'C1-2Ab: Optimisation of Fuel Enrichment, Fuel Burn-up and Fuel Cycle'*	The reactor fuel cycle, which can typically be varied from 12 to 24 months, influences the efficiency of fuel usage. Exploratory work was performed to examine the impact of a longer cycle length on core neutronics. However, balancing poison burnout and fissile material depletion towards the end of a longer cycle leads to higher power peaking; this would be expected to adversely affect safety during normal and faulted conditions. The fuel cycle length therefore needs to be optimised giving due consideration to a complex range of factors including energy generation requirements, the economic performance of the fuel, radioactive waste production, the time and cost of refuelling outages, and spent fuel storage costs. The current design basis for the RR SMR Fuel Assembly [JAC20] comprises uranium dioxide (UO2) with a maximum enrichment of 4.95% and gadolinia poison. Two fuel assembly designs are utilised, based on optimised fuel enrichment and gadolinia content (higher enrichment and lower gadolinia, and vice-versa), to optimise power generation. The RR SMR core design is designed to operate a high average fuel burn-up of 50-60 GWd/te, on an 18-month fuel cycle and a 3-batch equilibrium core, to optimise power generation and depletion of fissile material, and the inventory of fission, actinide and activation products generated in the fuel. RR SMR will have a higher proportion of twice burnt assemblies loaded closer to the core centre to control shutdown margin and minimise power peaking.
Evidence	Examples of Evidence • SMR0000594_1: RR SMR Design Overview Report • SMR0005138_1: RR SMR Core Design Description • SMR0004523_2: Core Design at Iteration 6 • SMR0004986_1: Reactor Systems Design Description • SMR0004210_1: E3S Case Chapter 4: Reactor (Fuel & Core) • EDNS01000371047_3: UK SMR Design Summary • RQ01217 Neutron leakage and activation of materials	Examples of Evidence: • SMR0000594_1: RR SMR Design Overview Report • SMR0005138_1: RR SMR Core Design Description • SMR0004523_2: Core Design at Iteration 6 • SMR0004986_1: Reactor Systems Design Description • SMR0004210_1: E3S Case Chapter 4: Reactor (Fuel & Core) • EDNS01000371047_3: UK SMR Design Summary

Figure 27.3-2 Summary of Claim 27.1, Sub-Claim 1-2A

Claims	Claim 27.1: The Design of the RR SMR Eliminates or Reduces the Generation of Radioactive Wastes and Spent Fuel (SF)		
	Sub-Claim 1-3A Detection and Management of Failed Fuel to Minimise the Release of Fission Products, Actinide Products and the Generation of Radioactive Waste		
Argument Summary	C1-3Aa: Monitoring and Detection Techniques to facilitate the rapid detection of failed fuel	C1-3Ab: Procedures in place for the Management of Failed Fuel	C1-3Ac: Access to Research and Development to ensure most relevant information used in dealing with Failed Fuel
	While measures described (in (C1-1A, C1-2A)) will be taken to ensure the integrity of the reactor fuel, the condition of the fuel will also be monitored during operations, including start-up and shutdown. Fuel monitoring will facilitate the rapid detection of a fuel pin failure, and initiate the action necessary to minimise the release of radioactivity into the primary coolant (C1-3Ab). Monitoring of fuel cladding failures during long-term storage of spent fuel in the Spent Fuel Pool (SFP), initiating action where necessary, will also minimise the discharge of activity into the SFP water.	In the event of a fuel pin failure, action will be taken to minimise overall eventual radiological releases to the environment, and the generation of radioactive waste in the coolant treatment systems. Response actions will vary depending upon the severity of the leak but in the extreme could result in reactor shutdown and fuel pin removal. Once the failed fuel has been removed and transferred to the Spent Fuel Pool (SFP), it will be cooled to minimise any release of fission products. In the SFP the cause of the failure will be established and long-term storage arrangements determined.	Rolls-Royce SMR has access to state-of-the-art research and development information, and operating experience (OPEX) data on several topics pertinent to fuel and core design and operation through membership of the Electric Power Research Institute (EPRI). Constellation are providing operational experience and advice on RGP Rolls-Royce SMR has commissioned the National Nuclear Laboratory and other competent organisations to carryout studies into different aspects of the design and operation of PWRs to inform the design of the RR SMR.
Evidence	Examples of Evidence: • E3S Case Chapter 9A: Auxiliary Systems • SMR0000983_2: System Outline Description for Handling of Nuclear Equipment [F] System • SMR0005383_1: System Design Description - Nuclear Sampling System [KUA] • SMR0005368_001: RI-045 - System Architecture for [KUA] & [KUF] Reactor Island Sampling Systems - Decision Record	Examples of Evidence: • E3S Case Chapter 9A: Auxiliary Systems • SMR0000983_2: System Outline Description for Handling of Nuclear Equipment [F] System • SMR0008057_1 Damaged Fuel Strategy	Examples of Evidence: • EDNS01000371047_3: UK SMR Design Summary

Figure 27.3-3 Summary of Claim 27.1, Sub-Claim 1-3A

Claims	Claim 27.1: The Design of the RR SMR Eliminates or Reduces the Generation of Radioactive Wastes and Spent Fuel (SF)			
	Subclaim 1-4A Control of Materials Corrosion and Activation to Minimise the Generation and Inventory of Corrosion Products			
Argument Summary	C1-4Aa: Specification of Reactor & Primary Circuit Materials to reduce activation and corrosion	C1-4Ab: Management of Reactor Coolant Chemistry to minimise generation of corrosion products and replacement of components due to corrosion.	C1-4Ac Removal of Corrosion Products from the Primary Coolant	C1-4Ad Commissioning, Start-up and Shutdown Procedures to incorporate measures to reduce corrosion of reactor internals
	Structural materials within a reactor can become activated due to their proximity to nuclear fuel and the associated neutron flux. These materials become radioactive waste when they are removed during maintenance and decommissioning tasks. Corrosion products that are suspended in the reactor water deposit on the surface of the fuel cladding and become activated. The activated elements can then re-dissolve into the reactor water, deposit on other reactor and pipe internals, and subsequently have the potential to contribute to an increase in dose to workers. The design of the RR SMR minimises this effect, so far as is reasonably practicable (SFAIRP), through: - selection of materials that are less susceptible to activation, corrosion and deposition (e.g. alloy 690) - reduction in the use of cobalt containing material such as stellite where acceptable alternatives are available. - preconditioning/treatment of surfaces that are in contact with the primary coolant, and passivation of such surfaces during plant commissioning.	The chemistry of the RR SMR primary coolant will be specified and managed in accordance with the primary coolant Water Quality Specification (WQS) to minimise the generation of corrosion products that could become activated in the reactor core, and thereby minimise the replacement of reactor and process components associated with material corrosion. The RR SMR primary coolant chemistry will be optimised – maintaining alkaline and reducing conditions during start-up and power operation phases, and oxidising conditions during shutdown – to minimise corrosion and manage the dissolution and removal of crud from the primary coolant through measures such as: - pH control (KOH addition) - zinc addition - hydrogen injection. - Management of the chemical environment to control ionic impurities such as chloride, fluoride and sulphate in the primary coolant.	The combined measures described in C1-4Aa and C1-4Ab are expected to significantly reduce, but not eliminate the generation of corrosion products. The design of the RR SMR incorporates additional measures to continually reduce the inventory of corrosion products in the primary coolant including: - Chemistry Volume and Control System (CVCS) purification system [KBE] - fuel assembly cleaning system [FBC]	Commissioning, start-up, shutdown and outage procedures will be developed for the RR SMR. These will incorporate measures aimed at reducing the corrosion of reactor internals, the consequential generation of activation products, and the ultimate production of radioactive waste. Measures include the use of nitrogen blankets to minimise aeration of coolant in storage during outages and degassing of the coolant before return to Reactor Coolant System (RCS) for start-up.
Evidence	Examples of Evidence: • E3S Case Chapter 20: Chemistry • SMR0005138_1: RR SMR Core Design Description • EDNS01000961566: Reactor Coolant Loop (RCL) Pipework Material Selection, • SMR0000517_2: Requirements Spec. for RC Pipework System [JEC]	Examples of Evidence: • SMR0000148_2: Reactor Island Water Chemistry Specification Tables, • SMR0000512: Small Modular Reactor Radioactive Source Term Policy • SMR0007674: Primary Water Chemistry – Minimisation of Fuel Cladding Corrosion • SMR0007673: Minimisation of radioactivity • SMR0007677 Chemistry Justification for Primary Coolant Systems	Examples of Evidence: • E3S Case Chapter 5: Reactor Coolant System & Associated Systems • SMR0000796_1:System Outline Description for Coolant Purification System • SMR0000983_2: System Outline Description for Handling of Nuclear Equipment [F] System	Examples of Evidence: • EDNS01000371047_3 UK SMR Design Summary • SMR0006900_1: Reactor Island Operating Philosophy • SMR0000594_1: RR SMR Design Overview Report

Figure 27.3-4 Summary of Claim 27.1, Sub-Claim 1-4A

Claims	Claim 27.1: The Design of the RR SMR Eliminates or Reduces the Generation of Radioactive Wastes and Spent Fuel (SF)			
	Sub-Claim 1-5A Control of Primary Coolant Chemistry to Minimise the Generation of Tritium and Carbon-14			
Argument Summary	C1-5Aa: Boron-free operation eliminates tritium generated from the neutron activation of boron and lithium	C1-5Ab Specification of Secondary Neutron Sources to minimise tritium generation	C1-5c: Degassing of demineralised make-up water and treated primary coolant	C1-5Ad Optimisation of spent fuel pool cooling to minimise evaporative loses of radioactive gases
	All commercial PWRs control reactivity throughout the fuel cycle by the use of boric acid dissolved in the reactor coolant. Boric acid comprises the isotope B-10 which has a high capture cross section for neutrons in the thermal part of the energy spectrum. The boric acid is, however, corrosive, and so to offset this effect lithium hydroxide is used for pH control. The presence in the reactor coolant of both boron and lithium results in the production of tritium, the majority of which is produced in the form of tritiated water. The tritium cannot practicably be abated and is thus ultimately discharged to the marine environment. The RR SMR will be operated soluble boron-free through the redesign of the reactivity control mechanism to eliminate the use of soluble boron for normal reactor control (as opposed to emergency usage). In terms of environmental benefits, boron-free operation reduces both discharges and the need for routine discharge of liquid effluent to manage tritium inventory, radioactive waste volumes and water processing requirements due to the elimination of deboration operations and the reduction in the generation of waste at source.	Current status - Secondary neutron sources shall not be included in the design of the reactor core. Analysis has shown that an acceptable signal can be monitored using ex-core detectors during reactor startup. In-core temporary fit neutron detectors shall be required to provide monitoring of the core during core load, until a number of fuel assemblies have been loaded and a signal can be monitored on the ex-core detectors.	Surface aeration of demineralised make-up water and primary coolant when in storage, for example during outage, could lead to oxidation and corrosion of metallic surfaces when the water is returned to the primary circuit. To minimise aeration, nitrogen cover gas is often used to blanket tanks holding treated primary coolant. However, dissolution of the nitrogen cover gas in the water eventually leads to enhanced generation of carbon-14 through neutron activation of nitrogen-14 when power generation recommences. The design of the RR SMR implements a low-pressure nitrogen cover gas network to minimise the dissolution of nitrogen in the primary coolant during storage. Demineralised water and stored primary coolant also undergo a degassing step prior to return to the RCS circuit, which strips dissolved gases (including nitrogen) from the coolant and minimises the generation of carbon-14 during power generation.	Controlling conditions in the spent fuel pool water is important to maintain the integrity of fuel cladding to ensure that the radioactivity remains inside the fuel, rather than escaping and being discharged to the environment. The key parameters controlled will be pool water temperature and chemistry. The surface area of pool has been minimised by incorporating fixed neutron absorbers within the fuel racks to increase storage density and reduce the overall footprint. For equivalent environmental conditions, a reduction in pool surface area will result in a reduction in evaporative losses. *Further information can be found in related argument:* C2b-1Ac, C3a-1Ab
Evidence	Examples of Evidence: • SMR0004982_001: E3S Case Chapter 20: Chemistry • SMR0000801_001: KBD Chemistry Control System Architecture Decision File • EDNS01000937657: PCD2 Boron-Free Decision (RI-1) • EDNS01000936264_001: A Fuel CRUD Chemistry Model for the UK SMR KOH/ Boron-Free Chemistry Regime • R01-547 – Alkalising Agent Selection – Chemistry Decision Record 2024 • SMR0007727_1 Chemistry Decision Record: Boron Free Environment 2024 • SMR0007705_1 Shutdown Chemistry Decision Record	Examples of Evidence: • SMR0004210_001: E3S Case Chapter 4: Reactor (Fuel & Core) • SMR0006583_2: Neutron Sources Assessment	Examples of Evidence: • SMR0000746: System Outline Description for the Processing and Treatment System for Gaseous Radioactive Effluent (KPL) • SMR0000632: SMR System Design Description for Liquid Radioactive Effluent Processing System	Examples of Evidence: • E3S Case Chapter 9A: Auxiliary Systems • SMR0006190 Technical Review: Spent Fuel Storage and Cask LoadingSystem [FAB] • SMR0000574 SDD for Fuel Pool Purification system [FAL] • SMR0000469_1 SOD for Fuel Pool Cooling System [FAK]

Figure 27.3-5 Summary of Claim 27.1, Sub-Claim 1-5A

27.4 Demonstration of Claim 27.2

27.4.1 Summary of Demonstration for Claim 27.2

Figure 27.4-1 to Figure 27.4-5 show the decomposition of claim 27.2 and provides the current argument headings, summarises the arguments, and identifies some of the key evidence that supports the demonstration that the design of the RR SMR can meet Claim 27.2: The Design of the RR SMR Minimises the Volume and/or Activity of Aqueous and Gaseous Radioactive Effluent Discharged to the Environment. The summaries provided in this chapter will be supported in future issues by detailed technical reports for each high-level claim.

The majority of SSCs are still in the early design stages and have not yet reached the design stage at which the final strategic option has been selected. Therefore, the arguments and evidence provided in Figure 27.4-1 to Figure 27.4-5 are not comprehensive, further work and development is required to fully demonstrate BAT for claim 27.2.

For this version, the summary figures provide an indication of how the argument(s) are progressing and identify key documents (references) that are available as supporting evidence. For certain arguments there may be limited or no current evidence, where possible the illustrative argument based on RGP/OPEX is provided.

The RR SMR design elements that are considered particularly important for claim 27.2 are:

- Provision of containment systems to prevent the uncontrolled spread of radioactivity into discharge systems and thus into the environment
- Provision of abatement systems to enable recycling of treated effluent and to remove radioactivity from waste before it is discharged to the environment
- Storage of wastes containing radionuclides with short half-lives prior to discharge which allows some of the radioactive to naturally 'decay'.

Taken together, these features are expected to minimise the activity of the radioactive waste discharged to the environment and to promote the exclusion of entrained matter in aqueous discharges.

Claims	Claim 27.2: The Design of RR SMR Minimises the Volume and/or Activity of Aqueous and Gaseous Radioactive Effluent Discharged to the Environment				
	Claim 27.2a: The leakage of primary and secondary coolant is minimised				
	Sub-Claim 2a-1A Primary Circuit Containment is designed to minimise, identify, and contain leaks from the Primary System.				
Argument Summary	C2a-1Aa Primary Circuit Containment is designed to minimise neutron leakage, uncontrolled releases and spread of contamination.	C2a-1Ab: Prevention and Minimisation of Leaks from the Primary Circuit by incorporating inherently less leak-prone equipment and leak detection equipment to aid the discovery and facilitate control	C2a-1Ac: Containment Leak Monitoring and Collection System to minimise and contain leaks from the containment, primary circuit, and the fuel pools.	C2a-1Ad: Containment Venting and Filtering system is designed to prevent the uncontrolled egress of radioactive gases and airborne particulates to the environment.	C2a-1Ae: The removed air will be treated using High Efficiency Particulate Air (HEPA) filters to remove airborne particulates prior to discharging to the external environment.
	The RR SMR reactor pressure vessel (RPV) [JAA], Nuclear Steam Supply System (NSSS) [JEA, JEB, JEC], and Containment System [JMA] are designed to minimise neutron leakage (and thus minimise arisings of activated materials which become radioactive wastes during the operational and decommissioning stages), prevent uncontrolled releases of radioactive materials to the environment, and limit the contamination of uncontrolled areas. See C1-2Aa for further information on neutron leakage The Containment Vessel (CV) [PT250] provides the main component of the containment function. Measures anticipated to reduce spread of contamination include isolation valves and appropriately sized vessels, designed and constructed to minimise leaks.	The risks of leaking radioactive materials from the Primary Circuit have been minimised by incorporating inherently less leak-prone equipment within the RR SMR's design. Furthermore, the RR SMR design incorporates a Primary Circuit Leak Detection System [JSS60] the purpose of which is to aid the discovery of leaks and enable implementation of appropriate management actions to contain leaks from the primary circuit and the fuel pools. *Further information is presented in C2a-1Ac*	The design of the RR SMR is looking at how best to deliver a leak detection function. Current recommendations are Type A rate testing using absolute pressure method utilising Heating, Ventilation and Air-Conditioning (HVAC) & leak testing using pneumatic pressure decay method. A Primary Circuit Leak Detection System [JSS60] and a Fuel Pools Leak Detection & Collection System [KTQ] are at early stages of design. The leak monitoring and collection systems are expected to minimise and contain leaks from the containment, primary circuit and the fuel pools. These systems are being designed in a manner that is consistent with established RGP.	The RR SMR Reactor Island (RI) HVAC system is designed to maintain a sub-atmospheric pressure condition to prevent the uncontrolled egress of radioactive gases and airborne particulates to the environment. The RI HVAC system will be configured to change the air from controlled areas (including the containment and annulus areas) either continuously - at a predefined rate - or periodically. Removed air will pass through High Efficiency Particulate Air (HEPA) filters. *Further information presented in C2a -1Ae and C2b-1Ab*	The removed air from the HVAC system will pass through HEPA filters which will remove airborne particulates prior to discharging air to the external environment. The discharge to environment will be sampled and monitored to ensure meets any limits. In-process monitoring will also be used to alert operators to any potential issues *Further information is presented in C2b-: 1Ab on filtration of gases.*
Evidence	<u>Examples of Evidence</u> • SMR0003771 E3S Case Chapter 6: Engineered Safety Features • SMR0005923: Decision Record for the In-Vessel Retention Function and the Reactor Vessel Cavity Injection System (RVCIS) • SMR0008536 - Safety Measure Description for Containment [JM01 • SMR0005089 Containment [JMA] System Design Description	<u>Examples of Evidence:</u> • EDNS01000928553: Primary to Secondary Leaks Decision Record	<u>Examples of Evidence</u> • SMR0000793: System Outline Description for the Level and Volume Control System • SMR0000402 SDD for Reactor Coolant System [JE] • SMR0000516 System Description for the Reactor Coolant Pipework System [JEC] • SMR0005666 TR1 Leak Detection & Monitoring	<u>Examples of Evidence:</u> • SMR00004702: System Design Description for the HVAC Systems Serving Controlled Areas and Uncontrolled Areas of Reactor Island (KL)	<u>Examples of Evidence:</u> • SMR00004702: System Design Description for the HVAC Systems Serving Controlled Areas and Uncontrolled Areas of Reactor Island (KL) • SMR0010323E3S Chapter 28: Sampling & Monitoring Arrangements

Figure 27.4-1 Summary of Claim 27.2a, Sub-claim 2a-1A

Claims	Claim 27.2: The Design of RR SMR Minimises the Volume and/or Activity of Aqueous and Gaseous Radioactive Effluent Discharged to the Environment		
	Claim 27.2a: The leakage of primary and secondary coolant is minimised		
	Sub-Claim 2a – 2A Secondary Circuit is designed to minimise, detect, and contain leaks		
Argument Summary	C2a-2Aa: Optimisation of Secondary Coolant System Chemistry to minimise the presence of impurities and conditions that could contribute to corrosion processes	C2a-2Ab: Monitoring for Steam Generator Leaks to enable the detection of leaks from the primary to the secondary circuits to aid discovery and facilitate control	C2a-2Ac The RR SMR Design will Minimise the Transfer of Radioactivity to the Secondary/ Turbine Coolant Circuit
	The RR SMR secondary circuit will be operated under a strict WQS regime to minimise the presence of impurities and conditions that could contribute to corrosion processes with the potential for transfer of radioactivity from the primary to the secondary circuit and eventually to the environment. The pH value in the Secondary Coolant System will be optimised to minimise the risks of corrosion, and especially flow-accelerated corrosion, of non-alloy or low-alloy materials that make up the system components in the turbine room, and reduce oxide transport to the Steam Generators (SG).	Transfer of primary coolant to the secondary circuit through SG tube leaks are treated as a frequent fault in PWRs and has been identified as an anticipated operational occurrence or expected event in the RR SMR. Such transfers result in the contamination of the secondary (turbine) coolant circuit and associated treatment systems with radioactivity, as well as the release of non-condensable radioactive gases via the Condenser Air Removal System (CARS) [MAJ]. The design of the RR SMR secondary coolant circuit and CARs [MAJ] makes provision for appropriate in-process radioactive monitoring equipment to enable the detection of leaks from the primary to the secondary circuits, and support the management decisions and actions to be implemented by the operator.	As described on C2a-2Ab transfer of primary coolant to secondary coolant can happen via SG leaks. The RR SMR design will apply established RGP – including appropriate standards (e.g. American Society of Mechanical Engineers (ASME)) and relevant RGP/OPEX (e.g. GB GDA NPPs, EPRI reports, etc.) – in the design of CARS. Other measures have been included within the RR SMR design to prevent/manage leaks these include careful selection of materials for the primary and secondary circuits , and pumps designed with canned rotor technology which suppresses the risk of leaks.
Evidence	<u>Examples of Evidence:</u> • SMR0003880: E3S Case Chapter 10: • SMR0002178: T01-003 Turbine Island System Decision Summary – [LB] System • SMR0001821: RR SMR Chemistry Justification Strategy Report. • SMR0001149: ESWS - C01-063 Blowdown Decision - Decision Record Sheet • SMR0000150: Turbine Island Water Chemistry Specification • SMR0008017 – Secondary Water Chemistry Method of Monitoring and Control – Due Jan 2024	<u>Examples of Evidence:</u> • SMR0005383: System Design Description – Nuclear Sampling System (KUA). • SMR0004860: System Design Description for the [LB] System. • SMR0002064: R01-477 Management of Active Steam Generator Blowdown	<u>Examples of Evidence:</u> • SMR0005085: System Design Description for the Steam Turbine System [MA] • SMR0002064: R01-477 Management of Active Steam Generator Blowdown

Figure 27.4-2 Summary of Claim 27.2a, Sub-claim 2a-2A

Claims	Claim 27.2: The Design of RR SMR Minimises the Volume and/or Activity of Aqueous and Gaseous Radioactive Effluent Discharged to the Environment Claim 27.2b: The discharge of gaseous radioactive waste to the environment is minimised		
Argument Summary	C2b – 1Aa: The design of the RR SMR incorporates delay beds allowing short-lived volatile fission radioisotopes to decay to very low levels.	C2b-: 1Ab Filtration of Gaseous Discharges to minimise radioactive particulate matter in gaseous discharges to the environment.	C2b-1Ac: The RR SMR Spent Fuel Pool will be designed to minimise the discharge of radioactivity to the outside environment through the installation of appropriate cooling measures to control evaporation.
	Decay storage takes advantage of a natural property of radioactive substances where the radioactivity progressively reduces over time. Retaining radioactive gases prior to discharge to allow decay to take place will reduce the activity of the gaseous wastes discharged to atmosphere. This is particularly relevant for those gases that are difficult to abate because they are not chemically active, such as the fission product noble gases krypton and xenon. The design of the RR SMR incorporates charcoal delay beds, a proven and widely used technology in nuclear power stations. The delay beds are configured to adsorb radioisotopes of krypton and xenon for periods of 40hrs and 40 days respectively, allowing short-lived radioisotopes to decay to very low levels.	Filtration is used to ensure that gaseous discharges to atmosphere are substantially free of radioactive particulate matter. The standard technique for the removal of particulate from gaseous effluents collected by HVAC systems in nuclear installations involves the use of HEPA filters with efficiencies in the range 99.95 – 99.99 percent The design of the RR SMR HVAC system incorporates HEPA filtration units consistent with global RGP for nuclear HVAC systems. Further, the design of the RR SMR HVAC system also incorporates iodine filters. Following HEPA filtration, the gaseous discharge stream can be re-routed via iodine filters, in the event that activity levels are detected above a certain level during normal operations. *Further Information C2a-1Ae*	The RR SMR design incorporates a Fuel Pool Cooling System (FPCS) [FAK] whose primary function is to remove heat from the fuel pools to maintain fuel pool temperature below 50 degrees centigrade. The FPCS [FAK] can be optimised to enhance the longevity of Ion Exchange (IX) resins in the Fuel Pool Purification System (FPPS) [FAL] and minimise the discharge of radioactivity to the outside environment through evaporation of SFP [FAB10] water. *Further information on SFP [FAB10] is presented in C1-5Ad Optimisation of spent fuel pool cooling to minimise evaporative loses of radioactive gases and C3a-1Ab: Control of Pool Water Temperature and Chemistry to maintain SF cladding integrity and prevent egress of radioactivity into the SF Pool.*
Evidence	<u>Examples of Evidence:</u> • SMR0004052 E3S Case Chapter 11: Management of Radioactive Waste • SMR0004289 Chapter 29: Quantification of Radioactive Effluent Discharges and Proposed Limits	<u>Examples of Evidence:</u> • SMR0004702: System Design Description for the HVAC Systems Serving Controlled Areas and Uncontrolled Areas of Reactor Island (KL) • SMR0005085: System Design Description for the Steam Turbine System [MA] • ENDS01000900096: Gaseous Waste Management Optioneering	<u>Examples of Evidence:</u> • SMR0000469: System Outline Description for the Fuel Pool Cooling System [FAK] • E3S Case Chapter 9A: Auxiliary Systems • SMR0006190 Technical Review: Spent Fuel Storage and Cask Loading System [FAB] • SMR0000574 SDD for Fuel Pool Purification system [FAL]

Figure 27.4-3 Summary of Claim 27.2b

	1A	3A		4A
Claims	Claim 27.2: The Design of RR SMR Minimises the Volume and/or Activity of Aqueous and Gaseous Radioactive Effluent Discharged to the Environment			
	Claim 27.2c: The discharge of aqueous radioactive waste to the environment is minimised			
	Sub-Claim 2c – 1A Liquid Effluent Management to minimise aqueous discharges to the environemnt	Sub-Claim 2c – 3A Evaporation of liquid discharges to minimise aqueous discharges to the environment.		Sub-Claim 2c – 4A Prevention and minimisation of leaks
Argument Summary	C2c-1Aa: The design of the RR SMR facilitates segregation of the incoming effluent streams as close to the point of generation as possible.	C2c-3Aa: Evaporation of treated effluent to produce a high purity distillate stream that can be recycled in the Primary Circuit	C2c-3Ab: Evaporation of Non-recycled Effluents from the Primary Circuit to concentrate activity in solid form and minimise radioactive substances in aqueous discharges to the environment	C2c-4Aa Systems are designed and manufactured to ensure minimise leaks.
	The effectiveness of effluent treatment is facilitated by the segregation of the incoming effluent streams as close to the point of generation as possible. This enables the application of the most effective treatment techniques which in turn maximises the potential for recycle, and ensures that as much radioactivity as practicable is removed from liquid effluent streams and converted into solid waste	Evaporation is an established technology for the treatment of liquid effluent streams. The technology produces distillate and concentrate fractions, which can then either be recycled or disposed of. The use of evaporation to concentrate activity in solid form minimises the release of radioactive substances to the environment. The design of the RR SMR Liquid Effluent Treatment System [KNF20] incorporates a waste evaporator for treating spent liquid effluent with relatively high chemical contamination (e.g. sodium or chloride ions), including the reverse osmosis (RO) retentates. Evaporation achieves a high purity distillate stream that can be recycled as demineralised water and stored in the treated liquid effluent storage tanks (as per the RO abatement train). The evaporator concentrates are transferred to the Solid Radioactive Waste Storage System (KME) for decay storage before being transferred to the Solid Radioactive Waste Processing System (KMA) for encapsulation.A vacuum evaporator is proposed to reduce the operating temperature and decrease corrosion risk.	Evaporation is also used for those effluents where concentration and subsequent containment of activity (and chemical components) is necessary to minimise discharges to the environment and where the activity cannot be readily removed by the methods of filtration and demineralisation Evaporation is thus normally only carried out for effluent from the chemical drains and is not routinely applied to all spent liquid effluents from the primary circuit Segregation of effluents allows evaporation to be used on appropriate streams. Evaporation produces a concentrate fraction which will go for decay storage prior to being transferred to the Solid Radioactive Waste Processing System for treatment and ultimately disposed of as a solid waste.	Design, manufacture and management of systems are compatible with substances they need to contain, and are suitable for operating conditions, for example: • Pipework will be designed to minimise connections • Ensure reliable isolation for EMIT • Minimise embedded pipes and components • Reinforced leak tightness requirements are set for active parts • Floors are equipped with a drainage and collection systems
Evidence	<u>Examples of Evidence:</u> • SMR0000632_2.SDD Reactor Island Drainage System [KTA] • SMR0000631_2 SDD Liquid Radioactive Effluent Treatment System [KNF] • EDNS01000893358_1 Spent Liquid Effluent Optioneering • SMR0006094: Liquid Effluent Chemistry Considerations and Proposed Work Prog. • SMR0000316: RI-161 Collection and Drainage of Radioactive Effluents Decision File	<u>Examples of Evidence:</u> • SMR0004052 E3S Case Chapter 11: Management of Radioactive Waste • SMR0000631_2 Liquid Radioactive Effluent Treatment System [KNF] • SMR0000092_1 SMR RFI - Reverse Osmosis • SMR0002131: Rolls-Royce Small Modular Reactor Integrated Waste Strategy • EDNS01000893361_1 – Primary Liquid Effluent Optioneering	<u>Examples of Evidence:</u> • SMR0004052 E3S Case Chapter 11: Management of Radioactive Waste • SMR0000631_2 Liquid Radioactive Effluent Treatment System [KNF] • EDNS01000893361_1 – Primary Liquid Effluent Optioneering • SMR0000315: Decision File - KNF Primary and Spent Fuel Effluent Processing and Treatment Train Merging	<u>Examples of Evidence:</u> • SMR0007922 Issue 1, September 2023. Secondary Water Chemistry: Minimisation of Corrosion of Structural Materials

Figure 27.4-4 Summary of Claim 27.2c, Sub-claims 2c-1A, 2c-3A and 2c-4A.

Claims	Claim 27.2: The Design of RR SMR Minimises the Volume and/or Activity of Aqueous and Gaseous Radioactive Effluent Discharged to the Environment				
	Claim 27.2c: The discharge of aqueous radioactive waste to the environment is minimised				
	Subclaim 2c-2A Coolant & Liquid Effluent Treatment minimises aqueous discharges to the environment.				
Argument Summary	C2c-2Aa: Effective treatment of the Segregated Waste Streams to maximise recycling of liquid effluent and minimise discharges to the environment.	C2c-2Ab: The design of the RR SMR employs Ion exchange (demineralization) technologies for the removal of soluble salts from aqueous effluent streams.	C2c-2Ac: Selection of Ion Exchange Resins to maximise the capture of salts and minimise the amount of waste ultimately discharged to the environment following the resins' waste treatment.	C2c-2Ad: Filtration of Liquid Discharges to remove radioactive particulate matter from aqueous discharges.	C2c-2Ae: Decay Storage of Liquid Effluent Prior to Discharge to minimise short lived radionuclides in aqueous discharges to the environment.
	Radioactive liquid effluents will be collected and treated in the Liquid Radioactive Effluent Treatment [KNF] System based on their source and expected levels of contamination, KNF design is based on general expectations of liquid effluent composition, the boron-free coolant chemistry and the desire to maximise recycling of effluent as process quality water around the facility. KNF will employ a variety of techniques to minimise discharges including pre and post filtration, reverse osmosis, demineralization, concentration and evaporation. Not all streams will require evaporation	The design of the RR SMR employs Ion exchange (demineralization) technologies for the removal of soluble salts from aqueous effluent streams via adsorption onto ion exchange resins, consistent with RGP. The technique is used in conjunction with filtration for the clean-up of reactor coolant and spent effluent. A resin has a finite capacity, and once it can no longer operate as an effective adsorbent, it, along with its adsorbed salt, is removed and sent for decay storage prior to solid waste treatment. Appropriate in-process monitoring equipment are incorporated into the design of the RR SMR liquid effluent treatment systems to monitor the efficacy of ion exchange columns.	The resins, or resin combinations, required to perform demineralization in the RR SMR will be selected to maximise the capture of salts and minimise the amount of waste ultimately discharged to the environment following the resins' waste treatment. The ion exchange medium ultimately chosen will depend upon the properties of the target ion, the presence of other competing ions in the feed stream, availability and cost.	Filtration minimises radioactive releases to the environment through the removal of radioactivity in particulate form and is standard practice in the nuclear industry. RR SMR incorporates pre-and post-filtration of liquid effluent using back-washable filters, for standardisation with Chemistry and Volume Control (CVCS) filters. Backwashing retained solids from filters reduces the activity of the filter media, so a filter change machine is not required. Filter solids will be transferred for decay storage prior to the Solid Radioactive Waste Processing System [KM] for processing. Filter design will be determined by discussion with suppliers. Reverse Osmosis units will be incorporated into KNF to remove particulates	Liquid Radioactive Effluent Treatment [KNF] System is designed in accordance with international RGP. The system will employ discharge tanks to enable radioactive decay of the short-lived radionuclides by storing effluents for a period of time to reduce the total amount of radioactivity discharged into the environment. The total reduction in activity depends upon the duration of storage. Decay storage typically has only limited effect in reducing the overall radioactivity in a PWR's liquid discharge. However, it is a simple management technique which produces no secondary wastes. KNF tanks are designed and sized for three major functions – providing excess storage capacity for recyclable effluents, monitoring & sampling of effluents to determine suitability for next step and discharge of effluents that are non-recyclable
Evidence	Examples of Evidence: • SMR0000632_2. SMR SDD Reactor Island Drainage System [KTA • SMR0000631_2 SDD Liquid Radioactive Effluent Treatment System [KNF] • SMR0000316 Collection and Drainage of Radioactive Effluents Decision File • SMR0000315 Primary and Spent Fuel Effluent Processing and Treatment Merging	Examples of Evidence: • IAEA Combined methods for liquid radioactive waste treatment: 1997-2001 TECDOC. 1336, 2003 • SMR0000631_2 SDD Liquid Radioactive Effluent Treatment System [KNF]	Examples of Evidence: • EPRI, Radioactive Liquid Processing Guidelines, Technical Report, 1011728, November 2005 • SMR0000631_2 SDD Liquid Radioactive Effluent Treatment System [KNF	Examples of Evidence: • SMR0000631_2 SDD Liquid Radioactive Effluent Treatment System [KNF • RR Report RI 284 Backwashable Filters • SMR0004502_2: E3S Case Chapter 11: Management of Radioactive Waste • RQ1089 Reverse Osmosis	Examples of Evidence: • SMR0002131_3: RR SMR Integrated Waste Strategy • EDNS01000893361_1 – Primary Liquid Effluent Optioneering • SMR0004486/002: Chapter 29: Quantification of Radioactive Effluent Discharges and Proposed Limits

Figure 27.4-5 Summary of Claim 27.2c, Sub-claim 2c-2A

27.5 Demonstration of Claim 27.3

27.5.1 Summary of Demonstration for Claim 27.3

Figure 27.5-1 to Figure 27.5-3 show the decomposition of claim 27.3 and provides the current argument headings, summarises the arguments and identifies the key evidence that supports the demonstration that the design of the RR SMR can meet Claim 27.3: The Design of the RR SMR Minimises the Volume and Activity of Solid and Non-Aqueous Radioactive Waste Disposed of, to other Premises. The summaries provided in this chapter will be supported in future issues by detailed technical reports for each high-level claim.

The majority of SSCs are still in the early design stages and have not yet reached the design stage at which the final strategic option has been selected. Therefore, the arguments and evidence provided in Figure 27.5-1 to Figure 27.5-3 are not comprehensive, further work and development is required to fully demonstrate BAT for claim 27.3.

For this version, the summary figures provide an indication of how the argument(s) are progressing and identify key documents (references) that are available as supporting evidence. For certain arguments there may be limited or no current evidence, where possible the illustrative argument based on RGP/OPEX is provided.

The RR SMR elements that are considered particularly important for claim 27.3 are:

- Consideration of radioactive waste management arrangements throughout the development and design of the RR SMR
- Decommissioning requirements embedded into the design
- Implementation of onsite pre-treatment steps where feasible in the solid waste management system [KM] to allow effective offsite management including segregation of waste streams, decay storage, size reduction, decontamination carried out by the solid waste management system [KM]
- Fuel pool purification system [FAL] and control of fuel pool water parameters
- Utilisation of shielding where appropriate to reduce potential for materials to become activated

Claims	Claim 27.3. The Design of the RR SMR Minimises the Volume and Activity of solid and non-aqueous radioactive waste disposed of, to other premises.			
	Sub-claim 3a -1A Management of Spent Fuel Pool to minimise generation of radioactive waste.		Sub-claim 3a -2A Decay Storage of Solid Radioactive Waste to minimise activity of waste disposed of to other premises	
Argument Summary	C3a-1Aa: The design of the RR SMR Spent Fuel Pool incorporates a Fuel Pool Purification System whose primary function is to remove impurities from the fuel pools and to maintain fuel pool chemistry to within specification	C3a-1Ab: Control of Pool Water Temperature and Chemistry to maintain SF cladding integrity and prevent egress of radioactivity into the SF Pool.	C3-2Aa: Decay Storage of Wet Intermediate Level Waste (ILW) to allow the activity of these waste streams to be reduced, potentially to a level where these wastes can be disposed of as Low Level Waste (LLW).	C3-2Ab: Decay Storage of Dry Intermediate Level Waste (ILW) potentially to a level where these wastes can be disposed of as LLW
	The Spent Fuel Pool (SFP) [FAB10] provides storage and initial cooling of spent fuel assemblies pending their long-term storage and disposal. FAB10 incorporates a Fuel Pool Purification System (FPPS) [FAL], whose primary function is to remove impurities from the fuel pools and to maintain fuel pool chemistry to within specification. It comprises two purification trains containing mixed bed resin ion Exchange Columns (IXCs) and backwashable filters. A continuous flow of spent fuel pool coolant is circulated through the FPPS [FAL] in normal operation to purify the coolant.	Significant majority of spent fuel assemblies will have intact cladding when they arrive at the fuel pool. By controlling conditions in the pool water, it is expected that cladding integrity will be maintained throughout the period of storage. This will ensure that the radioactivity remains inside the fuel, rather than escaping and being discharged or disposed of to the environment as waste. The key parameters controlled will be pool water temperature and chemistry. RR SMR incorporates a Fuel Pool Cooling System (FPCS) [FAK] whose primary function is to remove heat to maintain fuel pool temperature below 50 Degrees C. *Further info C2b-1Ac.* The FPCS [FAK] can be optimised to enhance the longevity of IX resins in the FPPS [FAL] and minimise the discharge of radioactivity to the outside environment through evaporation of SFP [FAB10] water. [FAL] provides a connection for the infrequent dosing of chemicals to the SFP [FAB10] to maintain the desired chemistry. The Fuel Cleaning, Inspection and Repair System [FBA] shall provide a means of encapsulating grossly damaged fuel assemblies to form a secondary containment barrier and mitigate the impact of damaged fuel on pool water chemistry.	The management of wet ILW predicted to arise from the RR SMR will take advantage of the natural process of radioactive decay to change the category of some ILW streams to Low Level Waste (LLW), enabling the use of alternative waste disposal routes. Decay storage is an effective strategy for managing ILW containing short- and medium-lived radionuclides (such as manganese-54, iron-55 and cobalt-60,) as it does not require any mechanical or chemical waste treatment and does not normally generate secondary radioactive discharges during the storage period. Consistent with RGP, predicted arisings of wet ILW streams and ILW/LLW boundary waste stream from the RR SMR (comprising spent resins, evaporator concentrates and filter back-wash sludges) will be decay stored in the RR SMR ILW storage facility [KME20]. This would allow the activity of these waste streams to be reduced, potentially to a level where these wastes can be disposed of as LLW.	Similar to the proposed approach for managing wet ILW, predicted arisings (comprising, spent filters and miscellaneous dry active waste (DAW) such as removed plant components, etc. generated during routine maintenance) from RR SMR operations will be collected in robust shielded containers in KME10 then transferred to KME30 for decay storage or to FKA for decontamination depending on dose rate and other factors. Some None Fuel Core Components (NFCC) will be co-disposed with spent fuel, whilst NFCCs that will be handled independently of spent fuel will likely be packaged in robust shielded containers similar to ILW DAW then decay stored in KME30. DAW may be reclassified following decay storage to enable disposal as LLW but for the DAW that does not decay to LLW and for the NFCCs they will be disposed of to the Geological Disposal Facility (GDF).
Evidence	Examples of Evidence: • SMR0005581: R01-501 - Fuel Storage Requirements and Strategy Summary • SMR0004846: SDD for the Spent Fuel Storage & Cask Loading System [FAB] • SMR0000983_002: SDD for Handling of Nuclear Equipment [F] System • SMR0008057 Damaged Fuel Strategy	Examples of Evidence: • SMR0005840: Cooling Water Systems [P] DR3 • SMR0001821: Chemistry Justification Strategy Report • SMR0000574 SDD for Fuel Pool Purification system [FAL] • SMR0000469_1 SOD for Fuel Pool Cooling System [FAK]	Examples of Evidence: • SMR0002131_2 RR SMR Integrated Waste Strategy • SMR0006485: Management of Dry Solid ILW • SMR0005687: Wet Solid Waste Cementation Facility Concept Design Study • SMR0005128: R01-525 Wet Solid Radioactive Waste Container Decision • SMR0000640: Optioneering for Grout Treatment of ILW and LLW Wet and Solid Wastes	Examples of Evidence: • SMR0000579: Optioneering of Methods for Treatment of Solid Radioactive Waste • SMR0006485: Management of Dry Solid Intermediate Level Radioactive Waste • Waste Facilities Basis of Design

Figure 27.5-1 Summary of Claim 27.3, Sub-claim 3a-1A and 3a-2A

Claims	Claim 27.3. The Design of the RR SMR Minimises the Volume and Activity of solid and non-aqueous radioactive waste disposed of, to other premises.				
	Sub-Claim 3a-3A Minimising Volumes of Operational and Decommissioning Waste Arisings				
Argument Summary	C3a-3Aa: Design for Decommissioning requirements are being incorporated to ensure most appropriate materials are chosen to reduce radiological dose to workers and volumes of solid radioactive waste requiring disposal.	C3a-3Ab: Shielding and Barriers will be utilised to reduce the activation of materials and to reduce the volume of active waste.	C3a-3Ac: The RR SMR design will minimise plant areas that might encounter radioactivity to aid maintenance and decommissioning operations	C3a-3Ad: Minimisation of Filter Usage & Disposal by ensuring filters are changed based on performance.	C3a-3Ae Modularisation of the RR SMR helps minimise decommissioning arisings
	Specific measures are being taken to minimise: the creation, transportation and deposition of contamination; the contamination/activation of rooms, systems and materials. Materials are chosen based on their likelihood to become radioactive, either by activation or by the deposition/absorption of contamination. Wherever possible equipment will be designed to be easy to clean (i.e. to remove surface contamination) and easy to disassemble (to allow separation of contaminated components) to aid maintenance and decommissioning, reducing both radiological dose to workers and volumes of solid radioactive waste requiring disposal. A number of decommissioning requirements have been incorporated into DOORS and these will be refined as design matures	Neutron shielding is utilised between the core and the reactor vessel to reduce irradiation of the steel and reactor compartment. This reduces the activation of materials and thereby facilitates the clean-up of the structures while reducing the volume of active waste. Layout is still being developed – which means that shielding requirements and assessments are at initial stages. Barriers will be used as a physical demarcation to help reduce spread of contamination	In line with standard practice the design will minimise plant areas that might come into contact with radioactivity and will thereby minimise volumes of irradiated waste from maintenance and decommissioning operations which will require disposal. Modularisation is a key difference between RR SMR and other PWR plants. *For further information on modularisation see C3a-3Ae.*	The volume of waste filters is minimised by ensuring that filters are changed based on differential pressure drop. They are replaced when performance drops (i.e. before they are blinded), as opposed to changing on the basis of pre-defined frequency.	The modular concept is advantageous for decommissioning. Disassembly of modular clusters may broadly be the reverse of assembly. The relative structural independence of each primary structure means that their removal (in reverse order) would not significantly compromise the remaining modular structure (cluster). Integral handling and transportation features could be used for their removal from the plant. Primary structures would inherently act as vehicles for the removal of Mechanical, Electrical and Plumbing (MEP) plant to where the equipment could be safely decommissioned. It is considered that the frame itself would pose no exceptional issues for decontamination and recycling. Modularisation development is ongoing.
Evidence	Examples of Evidence • Transverse requirements for Decommissioning in DOORS • SMR0008127: Decommissioning & Waste Management Plan • SMR0001861_1: Rad protection design guideline for RR SMR • SMR0000635_3: Dose Management Policy	Examples of Evidence • SMR0000636_2: (SMR Radiation Shielding Policy) • SMR0004769_ 2: (Active Waste Systems Bulk Shielding Assessment) • SMR0004091 Reactor Vessel Shielding • SMR0005401 The RPV Head Bulk shielding assessment -	Examples of Evidence • Transverse requirements for Decommissioning in DOORS • SMR0008127: DWMP • SMR0003308_1: Decision File for Strategy Decision (Decision 113) • SMR0004048: Decommissioning Strategy	Examples of Evidence • SMR0000746_2: SDD for Liquid Radioactive Effluent Processing System [KNF]. • RR Report RI-284 Backwashable Filters • EDNS010008933 58Liquid Monitoring and Discharge Optioneering	Examples of Evidence • SMR0007298 Architectural and Layout Summary Report • SMR0008277_2 Modularisation Kit of Parts Primary Structure Standard Frame Design Definition • SMR0008962 Modular Kit of Parts Strategy • SMR0004599 E3S Case Chapter 21 Decommissioning and End of Life Aspects

Figure 27.5-2 Summary of Claim 27.3, Sub-claim 3a-3A

Claims	Claim 27.3. The Design of the RR SMR Minimises the Volume and Activity of solid and non-aqueous radioactive waste disposed of, to other premises.		
	Sub-claim 3a-4A Application of Waste Management Processes and Techniques to Minimise Volume of Solid Waste Disposed of to Other Premises		
Argument Summary	C3a-4Aa: Design of the Waste Management Facilities to minimise volume of radioactive waste	C3a-4Ab: High Force and Low Force Compaction to minimise waste volume	C3a-4Ac: Incineration, Thermal Treatment and Metal Melting
	The volume of solid waste is reduced, so as far as is practicable, to make the most effective use of waste management infrastructure and reduce pressure on existing and future disposal facilities, while minimising the quantity of secondary wastes associated with waste management practices. A range of volume reduction techniques can be employed, including compaction and off-site incineration.	High and low force compaction will be used where appropriate as a volume reduction technique for RR SMR wastes. Current design status is that low force compaction will be available in [KMA 10} whilst high compaction is likely to be off-site and will be utilised as necessary.	Suitable solid radioactive wastes arising from the operation of the RR SMR will be sent for disposal via offsite incineration or metal melting. The main advantages of using incineration as a technique for treating combustible waste (once the waste is determined to be suitable for incineration) includes the significant volumetric reduction in the waste form which facilitates the increase in allocation capacity for more efficient use of volumetric and radiological capacity at the Low Level Waste Repository (LLWR) which is a national resource. Metal melting of suitable wastes allows the metal to be recycled.
Evidence	Examples of Evidence: • SMR0001123_1: SoD for Solid Radioactive Waste Processing System [KM] • SMR0002131_2: RR SMR Integrated Waste Strategy • EDNS 959134: Waste Basis of Design • SMR0007007 Waste Basis of Design • SMR 0000579: Optioneering of Methods for Treatment of Solid Radioactive Waste	Examples of Evidence: • SMR0002131 RR SMR Integrated Waste Strategy • SMR 0000579 Optioneering of Methods for Treatment of Solid Radioactive Waste • EDNS 884842 Operational Practices and Design Considerations to Minimise Waste in the UK SMR Design • Process – SMR0004683_3 BAT methodology and TS DD 02 Decision Record Template	Examples of Evidence: • SMR0002131 RR SMR Integrated Waste Strategy • SMR 0000579 Optioneering of Methods for Treatment of Solid Radioactive Waste • EDNS 884842 Operational Practices and Design Considerations to Minimise Waste in the UK SMR Design • SMR0004683_3 Approach for Optimisation trough the Application of BAT

Figure 27.5-3 Summary of Claim 27.3, Sub-claim 3a-4A

27.6 Demonstration of Claim 27.4

27.6.1 Summary of Demonstration of Claim 27.4

Figure 27.6-1 to Figure 27.6-3 show the decomposition of claim 27.4 and provides the current argument headings, summarises the arguments, and identifies some of the key evidence that supports the demonstration that the design of the RR SMR can meet Claim 27.4: The Design of the RR SMR Minimises the Impacts on the Environment and Members of the Public. The summaries provided in this chapter will be supported in future issues by detailed technical reports for each high-level claim.

The majority of SSCs are still in the early design stages and have not yet reached the design stage at which the final strategic option has been selected. Therefore, the arguments and evidence provided in Figure 27.6-1 to Figure 27.6-3 are not comprehensive, further work and development is required to fully demonstrate BAT for claim 27.4.

For this version, the summary figures provide an indication of how the argument(s) are progressing and identify key documents (references) that are available as supporting evidence. For certain arguments there may be limited or no current evidence, where possible the illustrative argument based on RGP/OPEX is provided.

The RR SMR design elements that are considered particularly important for claim 27.4 are:

- Preferential partitioning of isotopes into the liquid phase
- Incorporation of delay beds to minimise gaseous radioactive discharges
- Maximising dispersion of aqueous and gaseous discharges in the environment.

Claims	Claim 27.4. The Design of RR SMR Minimises the Impacts on the Environment and Members of the Public		
	Claim 27.4a: Radioactive waste (aqueous and gaseous) discharge routes and structures are optimised		
	Sub-claim 4a-1A Radioactive waste treatment systems incorporate process steps to ensure preferential partitioning into most appropriate waste stream		
Argument Summary	C4a-1Aa: Incorporation of moisture removal steps for drying non-condensable gases enables preferential partitioning of Tritium into Liquid Effluents	C4a-1Ab: Preferential Partitioning of Iodine isotopes in Liquid Effluents by utilising operational conditions favourable to the formation of non-volatile iodine species.	C4a-1Ac: Preferential Partitioning of Carbon-14 into Gaseous Discharges by incorporation of a vacuum degasser.
	The design of the RR SMR gaseous waste treatment system [KPL] incorporates multiple moisture removal steps for drying non-condensable gases stripped from the primary coolant before reaching the carbon delay beds, which has the effect of removing tritiated water vapours from the gaseous waste stream into liquid waste stream. The dose per unit discharge is higher for gaseous discharge of tritium than for liquid discharges; therefore, the preferential partitioning of tritium into liquid effluents minimises the radiological impacts of disposal into the environment. Further, the cooling system FPCS [FAK] fitted to the SFP [FAB10] is designed to keep the fuel pool water at temperatures below 50 Degrees C, which will control the evaporation of the pool water and the transfer of tritium to the gas phase.	The radiological impacts from iodine discharges (in terms of dose per unit release) are lower when discharged as a liquid rather than a gas. Iodine discharges are therefore preferentially retained in liquid effluents, although it is noted that iodine arisings are low compared to tritium production even during peak iodine production rates as a result of reactor start-up and shutdowns. The RR SMR implements a boron-free KOH operating chemistry and operates under a slightly alkaline and reducing environment during normal power operation phase. These conditions favour the formation of non-volatile iodine species, which partition to the liquid phase. The non-volatile iodine species have been shown to persist during low oxidation conditions during early shutdown phase. Volatile iodine species may be formed during latter shutdown phase, under more oxidising conditions. It is noted that during the shutdown phase, non-condensable gases are degassed from the primary coolant and transferred to the charcoal delay bed for treatment, where volatile iodine species would adsorb and be decayed.	The radiological impacts (in terms of dose per unit release) associated with discharges of carbon-14 tends to be higher in aqueous form than in gaseous form. The preferential partitioning of carbon-14 from the primary coolant into gaseous discharges is therefore advantageous because it is not practicable to partition appreciable amounts of the radionuclide to solid waste streams by means of abatement. The majority of discharges of carbon-14 into the environment (80 – 95 percent) are in the gaseous form, with typically only 5 to 20 percent being discharged in liquid and solid wastes (a characteristic of all operating PWRs). The design of the RR SMR liquid effluent treatment system [KNF] incorporates a vacuum degasser for stripping non-condensable gases (including carbon-14) from the primary coolant to the gaseous radioactive waste stream, which is directed to the gaseous waste treatment system [KPL] for the delay-decay of noble gases, before discharge to the outside environment.
Evidence	Examples of Evidence: • SMR0003863: E3S Case Chapter 9A: Auxiliary Systems • SMR0004486/002: Chapter 29: Quantification of Radioactive Effluent Discharges and Proposed Limits	Examples of Evidence: • SMR0004982: E3S Case Chapter 20: Chemistry • PWR iodine speciation and behaviour under normal primary coolant conditions: An analysis of thermodynamic calculations, sensitivity evaluations and NPP feedback, *Progress in Nuclear Energy*, 53, pg. 504-515.	Examples of Evidence: • SMR0004630/002: E3S Case Chapter 26: Radioactive Waste Management Arrangements • SMR0004486/002: Chapter 29: Quantification of Radioactive Effluent Discharges and Proposed Limits

Figure 27.6-1 Summary of Claim 27.4, Sub-claim 4a-1A

Claims	Claim 27.4. The Design of RR SMR Minimises the Impacts on the Environment and Members of the Public		
	Claim 27.4a: Radioactive waste (aqueous and gaseous) discharge routes and structures are optimised		
	Sub-claim 4a-2A Impact of Liquid Effluent Discharges is minimised	Sub-claim 4a-3A Impact of Gaseous Waste Discharges to the environment is minimised.	
Argument Summary	C4a-2Aa: Maximising Dilution and Dispersion of liquid effluents in the Marine Environment	C4a-3Aa: Height of Main Discharge Stack is optimised to ensure effective dispersion	C4a-3Ab Degassing and treatment of non-condensable gases from primary coolant during shutdown) to reduce impact of gaseous discharges.
	Surplus or off-specification liquid effluent arisings, following treatment in the RR SMR Liquid Radioactive Effluent Processing System [KNF], will be discharged to the aquatic [marine, lake or river] environment, where the discharged effluent will be diluted by the larger receiving water body. Dilution and dispersion of the discharged liquid effluent will be maximised by means of: a) Discharge into the much larger flow of the cooling water return will promote initial dilution; b) The discharge location will be selected to promote dispersion of the discharge in the marine environment; and c) Management of the discharges at each development site will take account of tidal, hydrological and geomorphological features and other factors that could affect the dilution and dispersion of radioactive liquid effluents. The design of the RR SMR implements the technique described in 'a.'. It is expected that future operators of the RR SMR will take account of site-specific factors and the discharge arrangements identified in 'b.' and 'c.'.	Waste gases from the RR SMR will be discharged to atmosphere via an exhaust stack the height of which will be optimised based upon the temperature and flow rate of the exhaust gases, the local topography and prevailing meteorological conditions, and sensitivity of the receiving environment. The stack will ensure that any residual gaseous radioactivity released to atmosphere minimises the radiological effects on members of the public and the environment. Rolls-Royce SMR Ltd commissioned an atmospheric dispersion modelling study to support the design of a generic RR SMR gaseous emission stack. The study indicated that for a site with flat topography and weather conditions typical of UK coastal locations, the benefits of increased stack heights begin to diminish around 65m. The outputs from this study will form an input into the design decision for the RR SMR stack, alongside other decision factors including engineering feasibility (civil/structural), visual impacts (architectural/planning), health & safety, and cost factors.	The design of the RR SMR incorporates charcoal delay beds, a proven and widely used technology in nuclear power stations. The delay beds are configured to adsorb radioisotopes of krypton and xenon for periods of 40hrs and 40days respectively, allowing short-lived radioisotopes to decay to very low levels before they are discharged to the environment. Allowing these short lived radionuclides to decay prior to discharge reduces potential doses to the public and non-human species from these radionuclides. *Further information is provided in C2b – 1Aa*
Evidence	<u>Examples of Evidence:</u> • SMR0006327/2: GR3 for Outfall System Decision 4.7 (C01-087. C01-088) – Rerun • SMR0005840: Cooing Water Systems (P) DR3 • EDNS01000894031: Liquid Monitoring and Discharge System Optioneering	<u>Examples of Evidence:</u> • EDNS01000884842: Operational Practices and Design Considerations to Minimise Waste in the UK SMR Design • Rolls-Royce SMR, Effluent Stack Height Dispersion Model.	<u>Examples of Evidence:</u> • Chapter 29: Quantification of Radioactive Effluent Discharges and Proposed Limits • E3S Case Chapter 11: Management of Radioactive Waste

Figure 27.6-2 Summary of Claim 27.4a, Sub-claim 4a-2A and 4a-3A

Claims	Claim 27.4. The Design of RR SMR Minimises the Impacts on the Environment and Members of the Public			
	Claim 27.4b: Final disposal routes for solid, non-aqueous radioactive wastes and spent fuel are optimised			
	Sub-claim 4b-1A Radioactive waste management and storage facilities are optimised		Sub-claim 4b-2A Solid and non-aqueous liquid LLW routes are optimised.	Sub-claim 4b-3A High Active Wastes (HAW) and Spent Fuel (SF) routes are optimised.
Argument Summary	C4b-1Aa: Adequate provisions have been incorporated in the design to allow future management of predicted arisings of radioactive wastes by operators	C4b-1Ab: Use of Diversified Waste Routes to ensure optimal disposal route chosen	C4b-2Aa: All predicted arisings of solid and non-aqueous liquid LLW have established disposal routes in the UK	C4b-3Aa: All predicted Solid HAW and SF arisings are compatible with NWS Disposal Concepts and the UK's Proposed GDF
	Rolls-Royce SMR Ltd have adopted a requirements-led approach for the RR SMR to establish a clear definition of the design requirements for all SSCs. This approach enables decomposition and flow-down of requirements from higher to lower level SSCs to ensure that optimised design solutions are developed at every level. Requirements generated from E3S principles and legislative requirements ensure that waste minimisation and adequate storage are integrated into the design from the start. Initial waste inventories (including predicted waste categorisation) have been developed, inventories and categories will continue to be updated as design matures. Waste inventory database is being developed.	Utilising a greater range of waste management solutions allows for wastes to be segregated based on a narrower range of characteristics and transferred to an optimal waste route that will reduce final volumes disposed.	Initial waste inventories, including volumes, activities and resulting waste categories at time of generation and at disposal, and known uncertainties / assumptions have been developed. Anticipated treatment and disposal routes for each waste stream have been identified. For those identified as potentially going to LLWR, a LLW Technical note and a Waste Enquiry Form were shared with Nuclear Waste Services (NWS) to commence the 'Agreement in Principle' Process. Regular meetings take place. This is to ensure that all anticipated waste arisings have a disposal route, and to ensure RR SMR do not make any design decisions that could create LLW wastes that wouldn't have final disposal route. Reports will be updated and provided to NWS as waste streams are refined.	Initial waste inventories, including volumes, activities and resulting waste categories at time of generation and at disposal, and known uncertainties / assumptions have been developed utilising SDD's, source term information and OPEX. Anticipated treatment and disposal routes for each waste stream have been identified. For HAW and SF that will require disposal at GDF, information in the form of disposability case was shared with Nuclear Waste Services (NWS). Regular meetings take place. This is to ensure that all anticipated waste arisings have a disposal route, and to ensure RR SMR do not make any design decisions that could create wastes that wouldn't be suitable for disposal at LLWR or GDF. Disposability case will be updated as inventories are refined
Evidence	Examples of Evidence: • SMR0002131_2: RR SMR Integrated Waste Strategy • SMR0005687: SMR Scope of Work - Wet Solid Waste Cementation Facility Concept Design Study • SMR0005128: R01-525 Wet Solid Radioactive Waste Container Decision • SMR0002131: Rolls-Royce Small Modular Reactor Integrated Waste Strategy • SMR0001122_2: Solid Operational Waste ID • SMR0000640: Optioneering for Grout Treatment of ILW and LLW Wet and Solid Wastes • SMR0000579: Optioneering of Methods for Treatment of Solid Radioactive Waste • EDNS01000884842: Operational Practices and Design Considerations to Minimise Waste in the UK SMR Design	Examples of Evidence: • SMR0002131 RR SMR Integrated Waste Strategy • SMR 0000579 Optioneering of Methods for Treatment of Solid Radioactive Waste • EDNS 884842 Operational Practices and Design Considerations to Minimise Waste in the UK SMR Design • TS DD 02 • SMR0004683_3 Approach for Optimisation through the Application of BAT	Examples of Evidence: • SMR0005649: Management of Liquid Organic Low Level Radioactive Wastes for the RR SMR • SMR00007016_1 Low Level Waste Arisings Technical Note • SMR0004630/2: E3S Case Chapter 26: Radioactive Waste Management Arrangements • SMR0002131: Rolls-Royce Small Modular Reactor Integrated Waste Strategy • SMR0001122: Solid Operational Waste Identification • SMR0000579: Optioneering of Methods for Treatment of Solid Radioactive Waste • EDNS01000935068: Optioneering of Methods for Transfer and Collection of Solid Radioactive Waste	Examples of Evidence: • SMR0004630/2: E3S Case Chapter 11: Management of Radioactive Waste • SMR0007665 RR SMR Disposability Case Report • SMR0002131: Rolls-Royce Small Modular Reactor Integrated Waste Strategy • EDNS01000935063: Optioneering of Methods for Treatment of Solid Radioactive Waste • EDNS01000935068: Optioneering of Methods for Transfer and Collection of Solid Radioactive Waste

Figure 27.6-3 Summary of Claim 27.4b

27.7 Conclusions

27.7.1 ALARP, BAT, Secure by Design, Safeguards by Design

Integration of BAT, ALARP, Secure by Design and Safeguards by Design into the engineering conduct design optioneering process for the RR SMR allows a holistic consideration and optimisation of all the key factors influencing design decisions. Integration into engineering processes provides confidence that the final design solutions will demonstrate BAT, ALARP, Secure by Design and Safeguards by Design at a fundamental level from the outset.

Development of the E3S Case is ongoing and the framework, and the body of evidence required to demonstrate, BAT, ALARP Secure by Design and Safeguards by Design will continue to be developed and refined in an iterative manner as the design of relevant SSCs matures. This chapter specifically addresses BAT and summarises the current status, the aim at final issue is to demonstrate that RR SMR can meet the BAT claims.

Whilst not specifically included in the E3S Case at Version 2, it is worth noting that Sustainable by Design has also been incorporated into the conduct design optioneering process. E3S Case at Version 4 will include a dedicated chapter on sustainability.

27.7.2 Assumptions and Commitments on Future Dutyholder, Licensee, Permit Holder

Table 27.7-1: Assumptions and Commitments on Future Dutyholder/Licensee/Permit Holder

Assumption/Commitment	ID	Description
Commitment	C27.1	Future permit holder(s) will check that the BAT case applies to their specific site requirements. BAT will need to be demonstrated for the specific site, the aim of the generic case is to try and ensure there aren't big design changes. This is not about changes due to different regulatory framework but ensuring impact is still minimised and abatement processes are BAT for actual location of RR SMR in relation to habitats / species. Consideration will need to be given to those key aspects of the design that interact directly with the environment for example, cooling water abstraction and discharge structures, gaseous emission stack and associated environmental analysis parameters (for example presence and details of sensitive receptors) are elements likely to need careful consideration and additional modelling.
Commitment	C27.2	Future permit holders will incorporate a BAT methodology into their management procedures. Optimisation of BAT continues throughout the lifetime of the RR SMR and therefore the 'permit holder' will have to

Assumption/Commitment	ID	Description
		incorporate a BAT methodology into their management procedures and continue to apply BAT.
Commitment	C27.3	Future permit holders will continue to apply BAT and optimise processes based on operational feedback and learning from experience. Optimise processes following operational feedback gained from running plant either from their own experience or from other vendors and operators.
Commitment	C27.4	Any changes in legislation or new requirements are considered to ensure the generic design still represents BAT. The generic design meets existing UK legislative requirements and has also considered international requirements. When a specific site is identified, the 'permit holder' will need to confirm that there are no specific legislative requirements that would require a design change.
Commitment	C27.5	Any potential design changes or deviations from the generic design will be assessed holistically using appropriate BAT methodology to ensure changes and design continues to represent BAT.
Commitment	C27.6	The future permit holder will check that the generic design continues to represent BAT for each lifecycle phase. For example, during commissioning, operation, and decommissioning the operator will confirm that the assumptions made during the design phase are still applicable and represent BAT.
Commitment	C27.7	Future permit holders will continue to keep abreast of new technologies and techniques to ensure operations continue to be BAT. Where feasible, new technologies will be utilised where it can be demonstrated they meet BAT to further optimise processes. For example, advances in abatement should be utilised where the design allows for their use.
Commitment	C27.8	Examination, Maintenance, Inspection and Testing (EMIT) of SSCs will be undertaken as required by design and to preserve equipment qualification. SSCs must be appropriately maintained to perform their required function and help ensure waste generated is managed in accordance with BAT.

27.7.3 Conclusions and Forward Look

The generic E3S Case objective at Version 2 is 'to provide confidence that the RR SMR design will be capable of delivering the E3S fundamental objective as it developed from a concept design into a detailed design'. This confidence is built through development and underpinning of top-level claims across each chapter of the E3S Case, through supporting arguments and evidence. The top-level claim for chapter 27 is 'the RR SMR has been optimised through the application of BAT to prevent or, where not practicable, minimise the generation of radioactive wastes and discharges, to minimise the impacts on the environment and members of the public.'

The arguments and evidence presented to meet the generic E3S Case objective at Version 2 include the BAT methodology, radioactive waste policies and environmental guidance that are embedded and integrated into the design decision and optioneering process. A general set of environment and BAT design requirements, which will support the demonstration that the BAT claims are met, are established in the RR SMR requirements management system as non-functional system requirements and are applied to SSCs through engineering processes. The application of these processes supports the ongoing design of the RR SMR to minimise the generation of radioactive wastes and discharges, to minimise the impacts on the environment and members of the public.

Forward actions (FAs) have been developed to support the continual development of the E3S Case and build confidence that the RR SMR can deliver its fundamental E3S objective. The FAs that were captured in the BAT methodology and need to be completed to support the development of this chapter have been captured here for completeness and to aid transparency. FAs that are required to develop the arguments and evidence to support the individual BAT claims are captured in the technical reports being produced for each claim.

Table 27.7-2: Forward Actions Needed for further Development of Chapter 27

ID	Description	Date
FA27.1	Continue to develop arguments and evidence to demonstrate that the RR SMR can meet BAT claims and produce technical report for each claim	Dec 24
FA27.2	Regularly review methodology and update as necessary as the engineering design matures	Ongoing
FA27.3	Review completed decision record templates to confirm that BAT training and methodology are well understood, embedded in process effectively and incorporate any lessons learnt into training and methodology	Q3 2024
FA27.4	Incorporate key components of EPF methodology into BAT methodology	Q3 2024
FA27.5	Update decision record template following feedback and 12 months learning from experience (LFE) from using during design process	Q3 2023

27.8 References

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[5] Rolls-Royce SMR Limited, *IMS Process C3.2.2-2 Conduct Design Optioneering,* 2023.

[6] Rolls-Royce SMR Limited SMR0000627, Issue 2, "E3S Case Development and Management Arrangements," November 2023.

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[12] Rolls-Royce SMR Limited SMR0003036, Issue 1, "RR SMR Key Objectives and Design Criteria," October 2022.

[13] Rolls-Royce SMR Limited, "Sustainability Policy," 2022.

[14] Rolls-Royce SMR Limited, *GDA Boundary document,* 2022.

27.9 Glossary of Terms and Abbreviations

ALARA	As Low As Reasonably Achievable
ALARP	As Low As Reasonably Practicable
ASME	American Society of Mechanical Engineers
BAT	Best Available Techniques
BSS	Basic Safety Standards
BSSD	Basic Safety Standards Directive
CAE	Claims, Arguments and Evidence
CARS	Condenser Air Removal System
CV	Containment Vessel
CVCS	Chemistry and Volume Control System
DAW	Dry Active Wastes
DOORS	Dynamic Object-Oriented Requirements System
DRP	Design Reference Point
DWMP	Decommissioning and Waste Management Plan
E3S	Environment, Safety, Security and Safeguards
EA	Environment Agency
EMIT	Examination, Maintenance, Inspection and Testing
EPF	Environmental Protection Function
EPR16	Environmental Permitting (England and Wales) Regulations 2016
EPRI	Electric Power Research Institute
ESWS	Essential Service Water System
FA	Forward Action
FCD	Final Concept Definition
FMA	Functional Means Assessment
FOAK	First of a Kind
FPCS	Fuel Pool Coolant System
FPPS	Fuel Pool Purification System

GDA	Generic Design Assessment
GDF	Geological Disposal Facility
GR	Gate Review
HAW	Higher Activity Waste
HEPA	High-Efficiency Particulate Air
HVAC	Heating, Ventilation and Air Conditioning
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
ILW	Intermediate Level Waste
IMS	Integrated Management System
IPR	Independent Peer Review
IX	Ion Exchange
IXCs	Ion Exchange Columns
IWS	Integrated Waste Strategy
LFE	Learning from Experience
LLW	Low-Level Waste
LLWR	Low-Level Waste Repository
MEP	Mechanical, Electrical and Plumbing Plant
NFCC	Non-Fuel Core Component
NPP	Nuclear Power Plant
NRW	Natural Resources Wales
NSSS	Nuclear Steam Supply System
NWS	Nuclear Waste Services
OPEX	Operational Experience
PWR	Pressurised Water Reactor
RCS	Reactor Coolant System
RD	Reference Design

RGP	Relevant Good Practise
RI	Reactor Island
RO	Reverse Osmosis
RPV	Reactor Pressure Vessel
RR SMR	Rolls-Royce Small Modular Reactor
RSR	Radioactive Substances Regulations
SDD	System Design Description
SF	Spent Fuel
SFP	Spent Fuel Pool
SFAIRP	So Far As Is Reasonably Practicable
SG	Steam Generator
SSCs	Structures, Systems and Components
TR	Technical Review
UK	United Kingdom
WQS	Water Quality Specification