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Title

E3S Case Chapter 1: Introduction

Executive Summary

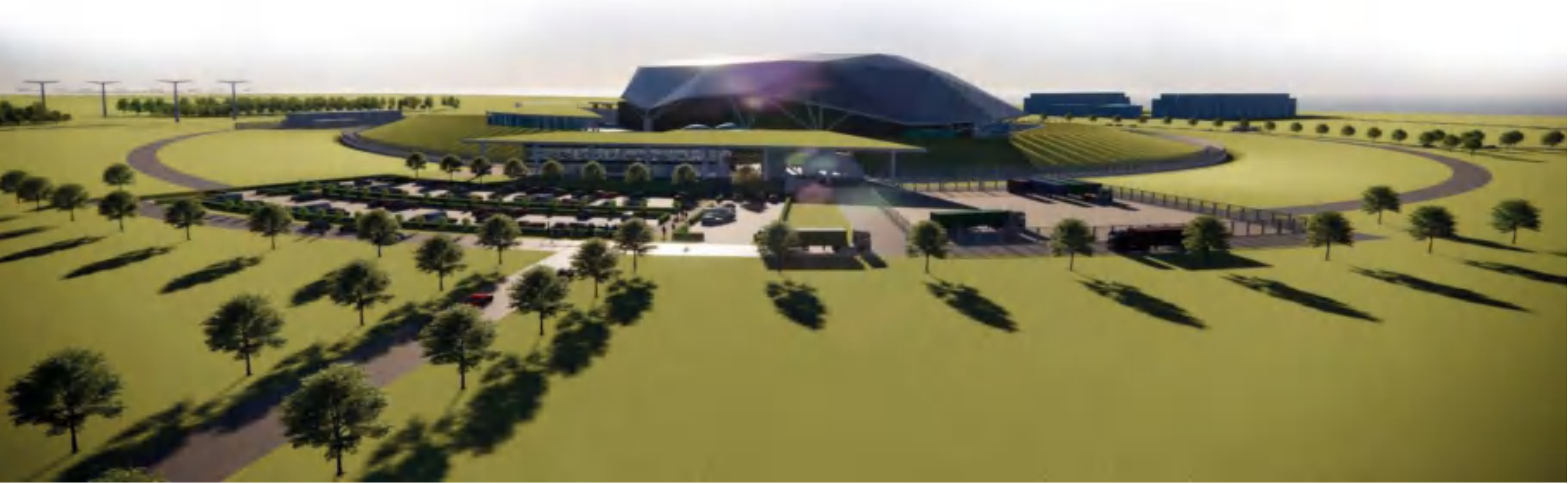
This chapter presents the Introduction to the Rolls-Royce Small Modular Reactor (RR SMR) Environment, Safety, Security, and Safeguards (E3S) Case at the Preliminary Concept Definition (PCD) design stage. The E3S Case is being developed alongside the ongoing design programme and will provide the overall justification that the fundamental objective 'to protect people and the environment from harm' can be achieved at all lifecycle stages of the power station and demonstrate that risks can be reduced to As Low As Reasonably Practicable (ALARP), applying Best Available Techniques (BAT), and ensuring Secure-by-Design and Safeguards-by-Design.

The E3S Case is developed in a hierarchical manner with three tiers of information. Tier 1 provides an overarching summary and entry point to the E3S Case and is comprised of 33 chapters (including this Introduction chapter). Tier 2 presents the first level of underpinning arguments and evidence, comprising a set of more detailed documents / data that can be easily referenced from the Tier 1 report. Tier 3 presents the detailed evidence that supports and is referenced from the Tier 2 documents / data. Claims, Arguments, Evidence is also used to provide a logical structure and framework for presentation of the overall E3S Case.

Tier 1 submissions are formed from relevant E3S Case Chapters, including the Pre-Construction Safety Report (PCSR) for the Safety Case and Safeguard Case, the Generic Environment Report (GER) for the Environment Case, and the Generic Security Report (GSR) for the Security Case. The integrated approach minimises repetition across the case and helps to maintain consistency.

A holistic E3S approach is embedded into the systems engineering approach for the RR SMR, which includes the centralised E3S team as key stakeholders supporting the design development and engineering processes, ensuring engineering outputs that provide evidence for the E3S Case incorporate the principles of ALARP, BAT, Secure-by-Design and Safeguards-by-Design.

An overview of the RR SMR engineering framework, plant layout, plant description, novel aspects of the design in comparison with other Pressurised Water Reactor (PWR) designs, and summary of environmental aspects is presented within this report, with reference out to other chapters of the E3S Case for further detail.



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1.1 Introduction

1.1.1 Purpose of E3S Case

Rolls-Royce Small Modular Reactor (Rolls-Royce SMR) are progressing the design and development of a Rolls-Royce Small Modular Reactor (RR SMR) power station. The RR SMR design programme is a phased design cycle, which commenced in May 2016 and aims to deploy the First of a Fleet (FOAF) RR SMR in the early 2030s.

The RR SMR has a fundamental objective 'to protect people and the environment from harm'. The Environment, Safety, Security & Safeguards (E3S) Case is being developed to provide the overall justification that the fundamental objective can be achieved at all lifecycle stages of the power station and demonstrate that risks can be reduced to As Low As Reasonably Practicable (ALARP), applying Best Available Techniques (BAT), and ensuring Secure-by-Design and Safeguards-by-Design.

The E3S Case comprises a series of 33 integrated chapters, listed in Table 1.1-1, that cover the broad scope of E3S. Chapter 1, presented within this report, provides an overall introduction to the E3S Case, including:

1. An overview of E3S Case approach and structure, including the hierarchical development of the E3S Case and use of Claims, Arguments, Evidence
2. Context of how the E3S Case supports the regulatory Generic Design Assessment (GDA) process, and details of the Rolls-Royce SMR organisation as the Requesting Party (RP)
3. Engineering arrangements that facilitate development of the E3S Case
4. General plant layout and description of the power station
5. An overview of novel features of the RR SMR in comparison to other Pressurised Water Reactors (PWRs)
6. A summary of the environmental aspects of the E3S Case

The purpose of Revision 1 of the E3S Case presented across these 33 chapters is to summarise the arguments and evidence, commensurate with the level of design maturity (described further in Section 1.1.2), to demonstrate that the fundamental objective can be achieved as the design and E3S Case matures.

1.1.2 E3S Case Maturity

The RR SMR is a developing design that is not based on a reference plant. Submissions of the E3S Case are aligned to design baselines (termed 'Reference Design (RD)'), which are aligned to engineering milestones in the design programme that correspond to an increasing level of design maturity, including Preliminary Concept Definition (PCD), Final Concept Definition (FCD), and Critical Definition Review (CDR).

Revision 1 of the E3S Case is aligned to the PCD engineering milestone at RD5, with a commensurate level of evidence to support the E3S demonstration for the preliminary concept design stage. The E3S Case will be updated and revised throughout the design programme (and subsequent lifecycle stages), as evidence is developed to reflect the increasing maturity of the design. This evolution is reflected in the simplified schematic in Figure 1.1-1, including an indication of the maturity in relation to GDA steps (described in Section 1.2 of this report).

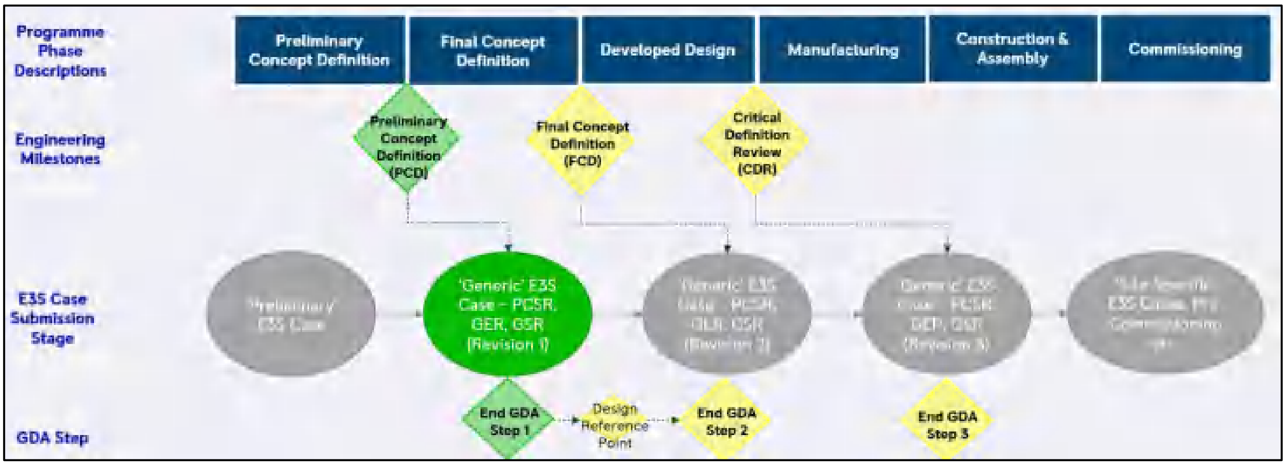

Figure 1.1-1: E3S Case Evolution alongside Design Programme

The overall evolution of the E3S Case through the facility lifecycle is described further in the E3S Case Development Strategy, Reference [1].

1.1.3 Holistic E3S Approach

The RR SMR is being developed with a systems engineering approach (described in Section 1.3), which includes the centralised E3S team as key stakeholders supporting the design development and engineering processes. As such, the practices to ensure ALARP, BAT, Secure-by-Design and Safeguards-by-Design are considered throughout the design evolution, and the outputs of the design development process provide a common evidence base for the E3S Case. There is also commonality of evidence across the various E3S analyses, such as hazard identification outputs.

For RR SMR, a holistic E3S Case is being produced, which will draw upon these common evidence outputs (as well as other non-common outputs) to demonstrate how the design protects people and the environment from harm, whilst reducing repetition of information within the E3S Case, supporting a consistent approach. It also allows the impact of design developments or changes to be understood more holistically.

Individual reports will still be developed for each of the E3S disciplines, described further in Section 1.1.4.

1.1.4 E3S Case Structure

The E3S Case will comprise many documents, therefore, to ensure its usability and accessibility for the different users and stakeholders, it is being developed in a hierarchical manner, comprising the following 'tiers' of information:

1. Tier 1: a series of integrated chapters covering the scope of the E3S Case, that provide an overarching summary and entry point to the arguments and evidence located in the lower

tiers. The level of detail will be summarised such that it is meaningful when read in isolation but will signpost to Tier 2 for an increased level of detail

2. Tier 2: the first level of underpinning arguments and evidence, comprising a set of more detailed documents/data that can be easily referenced from the Tier 1 report, that also signpost out to the detailed evidence on Tier 3

3. Tier 3: the detailed evidence for different aspects of the E3S Case, that supports and is referenced from the Tier 2 documents/data (noting at this revision there are instances where Tier 3 evidence is also referenced directly from the Tier 1 chapters as the structure is developing)

Tier 1 reports for each of the E3S disciplines will then be formed from relevant E3S Case chapters, including the:

1. Pre-Construction Safety Report (PCSR), which provides the entry point to the Safety Case and the justification of nuclear and conventional safety, also covering the demonstration of nuclear Safeguards arrangements. The PCSR chapters are broadly aligned to the expected contents of a safety report as outlined by the International Atomic Energy Agency (IAEA), Reference [2]; where possible, the IAEA chapter and section numbering/titles are followed to provide a standardised structure, noting this is adapted as necessary for United Kingdom (UK) context and current design maturity

2. Generic Environment Report (GER), which provides the entry point to the Environment Case and the justification of environmental protection. The GER chapters are broadly aligned to Environment Agency (EA) guidance, Reference [3]

3. Generic Security Report (GSR), which provides the entry point to the Security Case and the justification of Secure-by-Design. The GSR chapter is aligned to the expectations of the Office for Nuclear Regulation (ONR) Security Assessment Principles (SyAPs), Reference [4]

Development of the E3S Case as a series of integrated E3S chapters facilitates the holistic E3S approach, drawing upon a common evidence base, whilst minimising repetition of information across the chapters.

The E3S Case chapters, the Tier 1 reports they form part of, and a summary of their contents, are listed in Table 1.1-1. Where a chapter is not directly part of a Tier 1 report but contains information supporting its development, it is identified as a 'Key Reference (KR)' in the table. Where a chapter is not part of a Tier 1 report and is not a KR, it is identified as 'x' in the table.

Table 1.1-1: E3S Case Chapters

No.	Title	PCSR	GER	GSR	Summary of Contents
1	Introduction	✓	✓	KR	Provides an overall introduction to the suite of 33 chapters that make up the E3S Case

No.	Title	PCSR	GER	GSR	Summary of Contents
2	Generic Site Characteristics	✓	✓	x	Presents the site bounding characteristics and parameters within which the RR SMR is designed, such that it is capable of being built and operated in accordance with the standards of safety, security, safeguards, and environmental protection required in Great Britain (GB) throughout its entire lifecycle. Also presents a summary of the Generic Site Description (GSD) which environmental assessments are based on
3	E3S Objectives & Design Rules for Structures, Systems & Components	✓	KR	KR	Presents the key principles and associated methods, approaches, and requirements that provide the framework for the RR SMR to achieve its E3S objectives
4	Reactor (Fuel & Core)	✓	KR	KR	Describes the fuel and core design, including its composition and configuration of fuel, control rods, etc., and associated operational parameters
5	Reactor Coolant System & Associated Systems	✓	KR	KR	Describes the Reactor Coolant System (RCS) and associated systems, which include the Reactor Pressure Vessel (RPV) and the primary coolant circuit components
6	Engineered Safety Features	✓	KR	KR	Describes the systems which deliver the safety functions in response to fault and accident conditions in the reactor
7	Instrumentation & Control	✓	KR	KR	Describes the Control & Instrumentation (C&I) systems of the RR SMR which support delivery of the safety functions
8	Electrical Power	✓	KR	KR	Describes the electrical power systems which supply power to systems during both normal and fault conditions

No.	Title	PCSR	GER	GSR	Summary of Contents
9A	Auxiliary Systems	✓	KR	KR	Describes the auxiliary systems of the RR SMR, including the fuel handling and storage systems, water supply systems, and ventilation systems
9B	Civil Engineering Works and Structures	✓	KR	KR	Describes the civil and structural design aspects of the RR SMR, including the hazard shield and the base isolation system for protection against external hazards
10	Steam & Power Conversion Systems	✓	KR	x	Describes the steam and power conversion systems of the RR SMR that are primarily located in Turbine Island (noting some aspects cross the boundary into Reactor Island)
11	Management of Radioactive Waste	✓	KR	KR	Describes the radioactive waste treatment systems for RR SMR, and summarises the sources of solid, liquid, and gaseous waste streams
12	Radiation Protection	✓	KR	KR	Evaluates how radiation doses to onsite workers and members of the public will be controlled during normal operations, and describes the design features of the RR SMR that minimise exposures to ALARP
13	Conduct of Operations	✓	KR	KR	Presents how the RR SMR design and operational documentation will facilitate a future dutyholder/licensee to fulfil its prime responsibility to implement E3S requirements in operation
14	Plant Construction & Commissioning	✓	x	x	Presents a high-level overview of the proposed build and installation approach and programme for the RR SMR, and an overview of the proposed commissioning programme and associated strategies

No.	Title	PCSR	GER	GSR	Summary of Contents
15	Safety Analysis	✓	KR	KR	Presents the methods and outputs of the safety analysis that evaluate the RR SMR against relevant criteria and inform the design development, including the deterministic analysis of faults and accidents, probabilistic analysis, and internal and external hazard assessment
16	Operational Limits & Conditions	✓	KR	KR	Presents the processes to define the Operational Limits & Conditions (OLCs) in the design and safety analysis, to ensure they are successfully transferred into operational documentation
17	Management for E3S & Quality Assurance	✓	✓	KR	Presents the management and organisational arrangements to support the development of the RR SMR, including the processes and systems in place to ensure quality assurance and quality management of the design and E3S Case production
18	Human Factors Engineering	✓	KR	KR	Provides the demonstration that Human Factors (HF) is fully integrated into the RR SMR design and substantiation processes
19	Emergency Preparedness & Response	✓	x	x	Presents the UK and international regulations and good practice relating to emergency preparedness and response, and the design features and arrangements of the RR SMR that facilitate compliance
20	Chemistry	✓	KR	x	Presents the definition and justification of the RR SMR chemistry regime, chemistry specification for systems, and the design substantiation to meet chemistry specifications

No.	Title	PCSR	GER	GSR	Summary of Contents
21	Decommissioning and End of Life Aspects	✓	KR	x	Presents the RR SMR decommissioning and waste strategies for the RR SMR, and the provisions within the design to facilitate safe decommissioning
22	Conventional & Fire Safety	✓	x	KR	Presents the strategies for implementation of conventional and fire safety into design of the RR SMR, including Construction Design and Management (CDM)
23	Structural Integrity	✓	x	KR	Presents the RR SMR demonstration of structural integrity for safety-classified metallic pressure boundary components and their supports
24	ALARP Summary	✓	x	x	Presents the overarching summary of how the RR SMR reduces nuclear and conventional safety risks to ALARP through the lifecycle
25	Detailed Information about the Design	x	✓	KR	Presents a technical description of the facility's main plants, systems, and processes, which have a bearing on radioactive waste (solid, liquid and gaseous) generation, treatment, measurement, assessment and disposal, drawing upon information from other E3S Case chapters
26	Radioactive Waste Management Arrangements	KR	✓	KR	Presents the Radioactive Waste Management Arrangements (RWMA) for RR SMR, including solid waste quantities, and an overview of waste minimisation with focus on disposability and optimised disposal routes
27	Demonstration of BAT	x	✓	x	Presents a summary of how BAT methodology has been applied in the design of the RR SMR

No.	Title	PCSR	GER	GSR	Summary of Contents
28	Sampling Arrangements, Techniques, and Systems for Measuring and Assessing Discharges and Disposals of Radioactive Waste	x	✓	x	Presents the RR SMR sampling & monitoring arrangements for in-process and final discharge monitoring
29	Quantification of Radioactive Effluent Discharges and Proposed Limits	x	✓	x	Presents an assessment of potential discharges of aqueous and gaseous radioactive effluent from the RR SMR plant to the environment under normal operating conditions
30	Prospective Radiological Assessment at the Proposed Limits for Discharges and for any On-Site Incineration	x	✓	x	Presents the radiological assessment of doses to members of the public and non-human species. It describes the method used to calculate doses and justifies why the model's data and assumptions used are appropriate
31	Conventional Impact Assessment	x	✓	x	Presents conventional environmental aspects associated with RR SMR and how impacts are being managed to minimise taking into consideration legal requirements and Relevant Good Practice (RGP)
32	Security	KR	KR	✓	Presents the demonstration of Security in the design of the RR SMR, covering measures to ensure protection from sabotage, protection from theft, cyber security and information assurance, and to ensure Security-by-Design
33	Safeguards	✓	x	KR	Presents the demonstration that the design of RR SMR facilitates Safeguards through material accountability, and containment and surveillance (C/S)

Further detail on the development and justification of the overall structure and content of the E3S Case is presented in the E3S Case Development Strategy, Reference [1].

1.1.5 Claims, Arguments, Evidence

High-Level Claims, Arguments, Evidence

Rolls-Royce SMR are using a Claims, Arguments, Evidence (CAE) approach to structure the overall E3S Case in the demonstration of ALARP, BAT, Secure-by-Design and Safeguards-by-Design. High-level Claims are established based on the E3S Design Principles, Reference [5], which cover the scope of the E3S Case to achieve the overall objective to 'protect people and the environment from harm'.

A Claim is aligned to each chapter of the E3S Case and decomposed via Arguments into a set of Sub-Claims, to a level that links directly to an Evidence item that satisfies it. The approach for derivation of Claims, Sub-Claims and Arguments is presented in the E3S Case Development Strategy, Reference [1].

Definitions of the CAE terminology for the RR SMR E3S Case are as follows:

1. **Claim**: an assertion or statement that a high-level E3S goal is met, informed by the E3S Principles and aligned to the objectives of an E3S Case chapter. Examples include:

    a. Safety analysis has informed the RR SMR design to provide suitable and sufficient levels of Defence in Depth (DiD) to deliver the Fundamental Safety Functions (FSF), and reduce nuclear safety risks to workers and the public to ALARP

    b. The RR SMR Engineered Safety Features are designed and substantiated to achieve safety requirements through the lifecycle, and reduce risks to ALARP

2. **Sub-Claim**: logical decomposition of a top-level Claim informed by the E3S Principles, with as many levels of Sub-Claims as needed. Examples include:

    a. All credible Postulated Initiating Events (PIEs) for the RR SMR are identified, fully defined and sentenced appropriately for analysis

    b. The Emergency Core Cooling System (ECCS) is substantiated to achieve E3S Requirements

3. **Argument**: approach or methods to justify the links between Claims and their Sub-Claims, or lower-level Sub-Claims and their Evidence

4. **Evidence**: justification and underpinning of the Claims, Sub-Claims and/or Arguments

CAE in the E3S Case Hierarchy

The high-level CAE structure is aligned to the E3S Case hierarchy (described in Section 1.1.4) as follows:

1. **Tier 1**: the Claims, Arguments and Sub-Claims are contained within the top-tier of the E3S Case. For each 'lower-level' Sub-Claim, i.e., the lowest level of Sub-Claim in the chain, the associated Evidence satisfying the Sub-Claim is summarised, with a signpost to Evidence on Tier 2 for an increased level of detail

2. **Tier 2**: the first level of Evidence directly links upwards to the lowest Sub-Claim, which essentially provides the purpose for that Evidence item in the context of the E3S objective, and signposts downwards to the very detailed underpinning Evidence on Tier 3

3. **Tier 3**: provides the detailed Evidence for different aspects of the E3S Case, that supports and are signposted from the Tier 2 Evidence

A high-level CAE approach provides a logical structure and framework for the overall E3S Case, with traceability from the overall E3S objective down through to the detailed Evidence, and a clear purpose for each Evidence item in the context of the E3S Case, and increased visibility to highlight any gaps in Evidence. It is noted the content of the E3S Case and the demonstration of E3S is still presented as a narrative.

The CAE structure within the E3S Case hierarchy is illustrated in Figure 1.1-2.

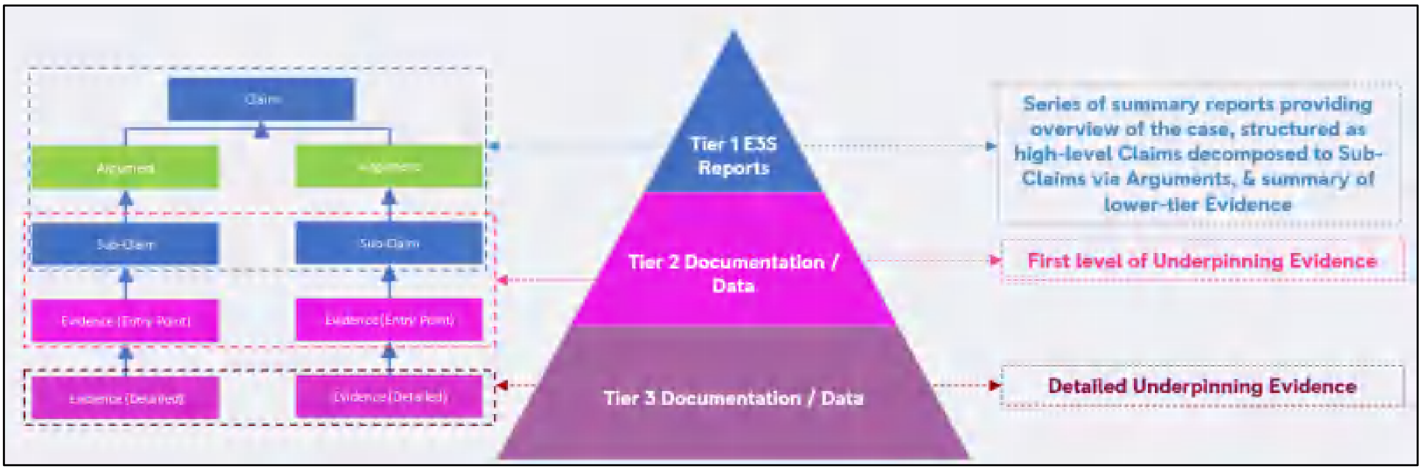

Figure 1.1-2: CAE Structure within the E3S Case Hierarchy

E3S Requirements

Detailed 'Claims' are also derived at the Structures, Systems & Components (SSCs) level, noting the terminology 'E3S Requirements' is used, which may include either E3S categorised functional requirements or non-functional system requirements (also termed 'transverse requirements'). Further information and examples of the types of E3S Requirements is described in Section 1.3.4.

E3S Requirements are part of the overall design requirements set, which have been derived from the E3S analyses and/or E3S Design Principles. They are stored and managed in the RR SMR requirements management 'Dynamic Object -Oriented Requirements System (DOORS)' database.

High-level Claims/Sub-Claims and E3S Requirements are inter-linked. For example, Sub-Claims relating to derivation or substantiation of E3S Requirements may reference to relevant DOORS modules which provide the underpinning Evidence at Tier 2 of the E3S Case.

Further information on the presentation of CAE and E3S Requirements is provided in the E3S Case Development Strategy, Reference [1].

1.1.6 E3S Case CAE Route Map

The RR SMR is currently in the concept design phase, with the E3S Case developing alongside the evolving design. As such, the suite of Evidence to underpin the Claims across the E3S Case in this revision is broadly at a low level of maturity. The suite of Evidence will continue to increase in maturity throughout the design programme and overall facility lifecycle.

The suite of documentation and data that will comprise the full E3S Case, i.e., Tiers 1, 2 and 3, is in the process of being mapped out in a CAE Route Map, Reference [6]. This route map presents the derivation of top-level Claims and subsequent decomposition of Sub-Claims and Arguments for each Tier 1 chapter of the E3S Case, linked to the Tier 2 and Tier 3 Evidence that underpins the Claims/Sub-Claims.

The CAE Route Map will also capture the progression in maturity of the underpinning Evidence corresponding to the engineering design programme, to provide confidence that Evidence will be being generated at a rate that provides a sufficiently comprehensive E3S justification that is appropriate to the lifecycle stage, and on the timescales required for regulatory assessment (see Section 1.2).

At this revision of the E3S Case, a snapshot of the CAE Route Map, where sufficiently developed, is presented in ‘Appendix A’ of each chapter, with the top-level Claim presented in the ‘Introduction’ section of each chapter. This snapshot presents a limited view of the Sub-Claims, Arguments, and associated Tier 2 Evidence, with a cross-reference to the relevant section within the chapter that provides the summary of Evidence.

Where Evidence is not available to be reported in the Tier 1 chapters at this revision, it will be included in future revisions of the Tier 1 report in line with the maturity outlined in the CAE Route Map.

1.2 Generic Design Assessment

1.2.1 GDA Background

The GDA is a voluntary process whereby Requesting Parties (RPs) submit their designs for new nuclear power plant to the Regulators: the ONR, EA, and Natural Resources Wales (NRW). The Regulators jointly review the designs to assess their acceptability for use in GB for safety, security, safeguards, environmental protection, and waste management.

The objective of the process is to provide confidence that a design is capable of being constructed, operated, and decommissioned in GB in accordance with the required standards for safety, security, and environmental protection. Further details of the GDA process are provided in Reference [7].

Rolls-Royce SMR entered the three-step GDA process in April 2022. Following a period of familiarisation and detailed planning during GDA Step 1, the information presented in the E3S Case will form the basis for regulatory assessment during GDA Steps 2 and 3, described further in Section 1.2.3.

1.2.2 Requesting Party

Rolls-Royce SMR are the vendor of the integrated nuclear power station. Rolls-Royce SMR are also the RP for the technology that is submitted into the GDA process.

Within the Rolls-Royce SMR organisation, the Safety & Regulatory Affairs Directorate is responsible for the provision of all safety, security, safeguards, and environmental input into the design development undertaken by the Engineering Directorate in an integrated manner. With respect to GDA, the Safety & Regulatory Affairs Directorate is also responsible for the delivery of the GDA programme.

The Engineering Directorate is responsible for the design and integration of the whole power station solution, configuration control of the design, the design analysis and engineering justification. Furthermore, the Engineering Directorate is responsible for ensuring product safety.

The Safety & Regulatory Affairs and Engineering Directorates are supported in the execution of their programmes by enabling functions within the organisation, including the Talent and Human Resources Directorate that is responsible for setting up frameworks to demonstrate Rolls-Royce SMR have suitably qualified and experienced personnel (SQEP) appropriately deployed in roles that have key responsibilities in delivering nuclear safety, conventional health and safety, security, and environmental protection in the design.

1.2.3 E3S Case Submissions during GDA

Unlike previous designs that have been submitted through the GDA process, the design of the RR SMR is not based on a reference plant, and the E3S Case is developing alongside the evolving design as described in Section 1.1.2. Submissions of the E3S Case will be made throughout each step of the GDA that are aligned to design baselines (termed ‘RDs').

Rolls-Royce SMR are also required to define and establish a Design Reference Point (DRP) for GDA. The DRP constitutes the suite of documents that represents a snapshot of the reference design that forms the basis of regulatory assessment. The initial DRP will be based on the design baseline during GDA Step 2, which will be updated as necessary to align with future design baselines in agreement with the regulators.

Rolls-Royce SMR will submit 'Issue 1' (i.e., this revision) of the Tier 1 reports of the E3S Case at the start of GDA Step 2, aligned to RD5 baselined at the PCD design stage. The purpose of this E3S Case submission is to provide the starting point for regulatory assessment at the start of Step 2.

Further Tier 2 and Tier 3 evidence will be submitted throughout GDA Step 2, aligned to a design baseline. The purpose of these submissions is to provide the basis for the fundamental regulatory assessment of the design during GDA Step 2. This set of documents, and any agreed changes and outcomes resulting from regulatory assessment during GDA Step 2, will be consolidated into 'Issue 2' of the Tier 1 chapters of the E3S Case at the start of GDA Step 3. It is noted that an interim issue of the GER will be submitted prior to the end of GDA Step 2, therefore those specific E3S Case chapters that comprise the GER will be re-issued at 'Issue 3' at the start of GDA Step 3.

Tier 2 and Tier 3 evidence will continue to be submitted throughout GDA Step 3, aligned to a design baseline. The purpose of these submissions is to provide the basis for more detailed regulatory assessment of the design during GDA Step 3. This set of documents, and any agreed changes and outcomes resulting from regulatory assessment during GDA Step 3, will be consolidated into a final 'Issue 3' of the Tier 1 chapters of the E3S Case at the end of GDA Step 3.

The full scope of GDA is presented in the Rolls-Royce SMR GDA Scope Document, Reference [8]. This is supported by individual scope and submission plans for each GDA topic area, which list the relevant Tier 2 and Tier 3 evidence and any exclusions.

1.2.4 Management Arrangements

The Rolls-Royce SMR management and organisational arrangements for production of the E3S Case are outlined in E3S Case Chapter 17: Management for E3S and Quality Assurance, Reference [9], including details of the governance and assurance arrangements for the E3S Case. Arrangements for response to Regulatory Queries (RQs), Regulatory Observations (ROs), and Regulatory Issues (RIs) during GDA are outlined in project operating instructions.

1.2.5 Assumptions & Commitments for the Future Dutyholder/Licensee

An essential element of the E3S Case development process is the capture and tracking of assumptions and commitments that are generated from the E3S Case, which need to be passed on to a future Dutyholder/Licensee. These include matters such as operating rules, maintenance requirements, training programmes, or emergency preparedness. They are defined as:

1. Assumption: Statements that enable work to continue but need validation before they can be confirmed as true

2. Commitment: An assumed obligation on a future Duty Holder/Licensee to conduct a specified activity

Assumptions and commitments will be captured throughout the Tier 1 reports of the E3S Case and summarised in the conclusions of each chapter. These will then be logged in an 'Assumptions and Commitments for future Dutyholders/Licensee Register' for ongoing management.

1.3 Engineering Framework

1.3.1 Systems Engineering Approach

The RR SMR programme is following a design-led, E3S-informed approach. It utilises, where appropriate, a set of systems engineering and robust design techniques to ensure that the integrated design solution is optimised to meet all key requirements, including E3S requirements that support demonstration that risks are acceptable and reduced to ALARP and that BAT is applied to optimise environmental impacts.

Systems design is, by nature, continuous and iterative. The E3S team are key stakeholders throughout the design process, involved in key activities described throughout Section 1.3, including derivation of requirements, optioneering and alignment to RGP, Operating Experience (OPEX), and analysis of options.

This section summarises the engineering arrangements of the RR SMR programme, with focus on the aspects that are relevant to development of the E3S Case. Further detail of the processes and controls summarised in this section is provided in the RR SMR Engineering Management Plan (EMP), Reference [10].

1.3.2 Key Design Objectives & Assessment Criteria

A consistent set of design objectives and assessment criteria have been defined for the RR SMR project to direct the progression of the design architecture/solutions based on market and functional needs. The objectives form part of the design decision-making process (see Section 1.3.5), used as the comparison criteria in the decision Pugh matrices to evaluate design options, providing a consistent framework to ensure progression of the design basis in line with the principle of ALARP, BAT, Secure-by-Design, and Safeguards-by-Design.

These key design objectives and criteria for the programme are summarised in Table 1.3-, which also includes a mapping of the criteria to the United Nations (UN) Sustainable Development Goals (SDG) and to the seven well-being goals defined in the Well-being of Future Generations (WoFG) (Wales) Act 2015.

A three-tier weighting score is shown in the table for each criteria, which provide a simplified numerical basis for quantification of judgments as to the relative priorities:

1. Weighting of 3 – Critical
2. Weighting of 2 – Major
3. Weighting of 1 – Significant

Full justification of the criteria and their weightings is provided in Reference [11].

Table 1.3-1: RR SMR Key Design Objectives

ID	Category	Key Objective	Metric	Weight	Sustainability Categories	UN SDG	WoFG
1	Safety	Must meet UK legislative requirements (licensable and permittable)	Risk of compatibility with UK regulatory and legislative requirements and the meeting of key principles and goals. Includes nuclear and conventional health and safety and environmental requirements.	3	E3S		Prosperous
2	Safety	Minimise need for operator reliability / maximise passivity	Measure of degree of operator intervention required (total claims on operator). How well does the option support this principle?	2	E3S		Healthier
3	Safety	Support continuous safety improvement, meeting the Basic Safety Objective (BSO) 1E-6 / yr but targeting 1E-7 Core Damage Frequency (CDF)/yr	CDF/yr. Safety comparison, looking at impact on fault schedule / Probabilistic Safety Assessment (PSA) and compatibility with safety targets.	3	E3S		Healthier
4	Safety	Minimise normal operation and maintenance dose to ALARP Levels	A measure of impact on potential worker and public dose, taking account of time, distance and shielding.	3	E3S		Healthier

ID	Category	Key Objective	Metric	Weight	Sustainability Categories	UN SDG	WoFG
5	Environm-ent	Minimise environmental impact: showing compliance with BAT principles for minimisation of conventional and radioactive waste and ensuring sustainable development	Estimates of the volume and activity of waste generated and effluent discharged via different routes over plant lifecycle including decommissioning. Clear adherence to BAT principles.	3	E3S		Prosperous Resilient Healthier
6	Security	Security compliance and continuous improvement	Qualitative judgement based on the impact of the option on meeting the security requirements. See security by design principles.	3	E3S		-
7	Cost	Minimise Overnight Capital Cost (capital cost comparison)	£/MW (compare capital cost impact difference between the options, considering broader plant impacts, factoring in any differential on potential power output as a result of the option)	3	Socio - Economic		Prosperous
8	Cost	Minimise Cost of Energy and associated impact(s) (through life cost factors)	£/MWhr Balance of maximising power output and minimising cost through life.	3	Economic, Environment, Social		Prosperous Globally Responsible
9	Cost	Minimise cost of decommissioning and associated impact(s)	£ (compare the impact on decommissioning complexity and costs)	1	Economic, Environment		Prosperous Globally responsible

ID	Category	Key Objective	Metric	Weight	Sustainability Categories	UN SDG	WoFG
10	Cost	Highly reliable and available (No unplanned maintenance and utilisation >90%)	Availability (% of time averaged over lifetime), taking account of planned maintenance needs and failure reliability	3	Socio-Economic, Environment		Prosperous
11	Program-me and Cost	Minimise build schedule duration	Compare manufacturing and build duration (yrs) (build target <3yrs)	3	Socio-Economic		Prosperous Cohesive communities
12	Program-me and Cost	Maximise modular build, standardisation and commoditisation	Contribution to achieving >60% power station modularisation. Consider comparison of weight and size, connectivity and standardisation potential of the option	3	Socio-Economic		Prosperous Cohesive communities
13	Program-me and Cost	Maximise use of proven technology (minimise development cost/risk)	Technology/ Manufacturing capability/Material readiness level assessment and development risk measured as a development cost (£) comparison, taking account of technology development and substantiation	1	E3S, Economic		-
14	Program-me and Cost	Compatible with existing UK / Global infrastructure and capability	Novelty of capability and infrastructure required to support this option at all stages of development and through life. Qualitative comparison of risk	2	Socio-Economic		Prosperous

ID	Category	Key Objective	Metric	Weight	Sustainability Categories	UN SDG	WoFG
15	Program-me	Development Programme Timescale	Risk to achieving deployment date - a measure of development programme timescale	2	Socio-Economic		Prosperous Resilient
16	Program-me	Enhanced UK public perception	Attractiveness to public - qualitative judgement regarding how appealing a feature would make the overall SMR. Covers aspects of aesthetics, siting and UK localisation intent (impact on jobs, security, environment etc.)	1	Socio-Economic		Prosperous Cohesive communities
17	Market	Maximise site availability and flexibility	Availability of sites (number of sites). How well the option maximises the potential sites compatible with the SMR deployment	2	Socio-Economic		Prosperous
18	Market	Capable of global expansion	Compatibility with global regulatory bodies and specific targeted regional requirements	2	Socio-Economic		Prosperous Globally responsible
19	Market	Optimised for base load power generation	Ability to support base load power unit performance as the primary mode. Compare maximum reliable top end power output level, within other constraints of size	1	Socio-Economic		Prosperous
20	Market	Compatible with alternative usage/ application to base load power as a secondary demand	Compatibility with alternative usage e.g., heat, flex (how well the option enables this). Compare ability to support flexible load following	1	Socio-Economic		Prosperous

1.3.3 Reference Designation System

Reference designation for SSCs within the RR SMR power station scope is implemented in accordance with the Standard Reference Designation System for Power Plants (RDS-PP). RDS-PP is internationally recognised and is referenced within the International Electrotechnical Commission (IEC)/International Organisation for Standardisation (ISO) 81346 series of standards. RDS-PP provides a unique designation for each plant object throughout planning, licensing, construction, operation, maintenance, and decommissioning.

A functional product breakdown structure has been developed for the RR SMR architecture, which assigns unique RDS-PP codes to SSCs using a hierarchical approach, from the power station (Level 0) to island (Level 1), to plant (Level 2), to system (Level 3), through to sub-system (Level 4) and component (Level 5).

The functional product breakdown structure enables consistent naming and designation of SSCs across the design of the RR SMR. The E3S Case is aligned to the functional product breakdown structure, with SSCs referred to by their RDS-PP ‘system’ code using a square bracket ‘[XX]’ throughout each chapter of the E3S Case.

1.3.4 E3S Requirements Management

General Requirements Management

Requirements management underpins a systematic approach to engineering design of systems and components. As part of the systems engineering approach, requirements are flowed from the programme to power station, to system and then to sub-system / component level in a clear, consistent, integrated, and traceable approach. The resultant hierarchical design then undergoes progressive verification and validation to demonstrate evidence-based compliance with the requirements set, and to give confidence that the solution meets the operational needs of the programme/customer.

Requirements are captured in the project’s DOORS database, in a structure that aligns to the functional product breakdown structure. Requirements management is a continuous process, applicable throughout the project delivery lifecycle. Requirements will be managed such that at each stage of definition or phase of project, there is a clearly defined and agreed set of approved and baselined requirements. Any change to these requirements shall be managed and communicated, with clear traceability of the reason for change and the impact of that change on the activity/design definition.

The management of requirements is part of a wider information framework that is collectively referred to as the Requirements, Evidence, Design Definition, Verification and Validation (REDV) information set, described below.

E3S Requirements

Requirements for a particular system are developed by stakeholders and documented within a requirements module in DOORS. E3S Requirements are part of the overall requirements set that feed into the requirements management process and REDV information set. The types of E3S requirements include:

1. Functional Requirements: functional requirements placed on an SSC to deliver an E3S function across all plant states, which are linked to the E3S analyses and categorised in accordance with their importance to E3S (note, 'safety' categorised functional requirements may also be termed Safety Functional Requirements (SFRs))

2. Non-Functional Performance Requirements: detailed numeric targets/ constraints/parameters linked to achieving E3S Functional Requirements (examples include rate of heat removal, flow rates etc.)

3. Non-Functional System Requirements: non-functional requirements which are derived from the E3S Design Principles and specify the architecture or property of an SSC, examples include reliability, redundancy, autonomy etc. (note are also termed 'Transverse Requirements')

E3S Requirements are derived across many areas of the E3S Case, including deterministic and probabilistic assessments, human factors assessment, radiological assessments, chemistry specifications, safeguards, etc. They are captured within the DOORS database to enable full traceability from the derivation source, e.g., in the Fault Schedule, through to their substantiation (as described below).

The outputs of design and E3S analyses will include requirements for Examination, Maintenance, Inspection and Testing (EMIT) and OLCs, which inform the specification of the Safe Operating Envelope (SOE) for operation of the plant. Further information on the process to ensure requirements are appropriately captured for plant operation is described in Chapter 16: Operational Limits & Conditions, Reference [12]

Design Definition

Definitions are developed by systems designers in conjunction with the E3S team and other disciplines, with the associated rationale recorded:

1. Concepts are generated as design solutions that can meet requirements, informed by RGP and OPEX, and assessed in line with the decision-making process and optioneering

2. Design solution is developed and refined with supporting calculations and analysis

3. Decomposition of functional and non-functional requirements that are allocated to each element of the system architecture (or to other systems/sub-systems), which are recorded within the allocated requirements module in DOORS with associated rationale evidence to how the position was reached, and links back to parent requirements

Verification

Verification strategies are developed which outline the verification activities and sequencing required to demonstrate the design definition complies with its requirements (e.g., physical test rigs, simulations, performance analysis etc.). This information is stored in a verification module in DOORS.

Structured Verification (SV) is an application of systems engineering principles. It takes a formalised, methodical approach to the planning and execution of verification activities, linking them back to the product requirements. The information flow within the process is illustrated in Figure 1.3-1.

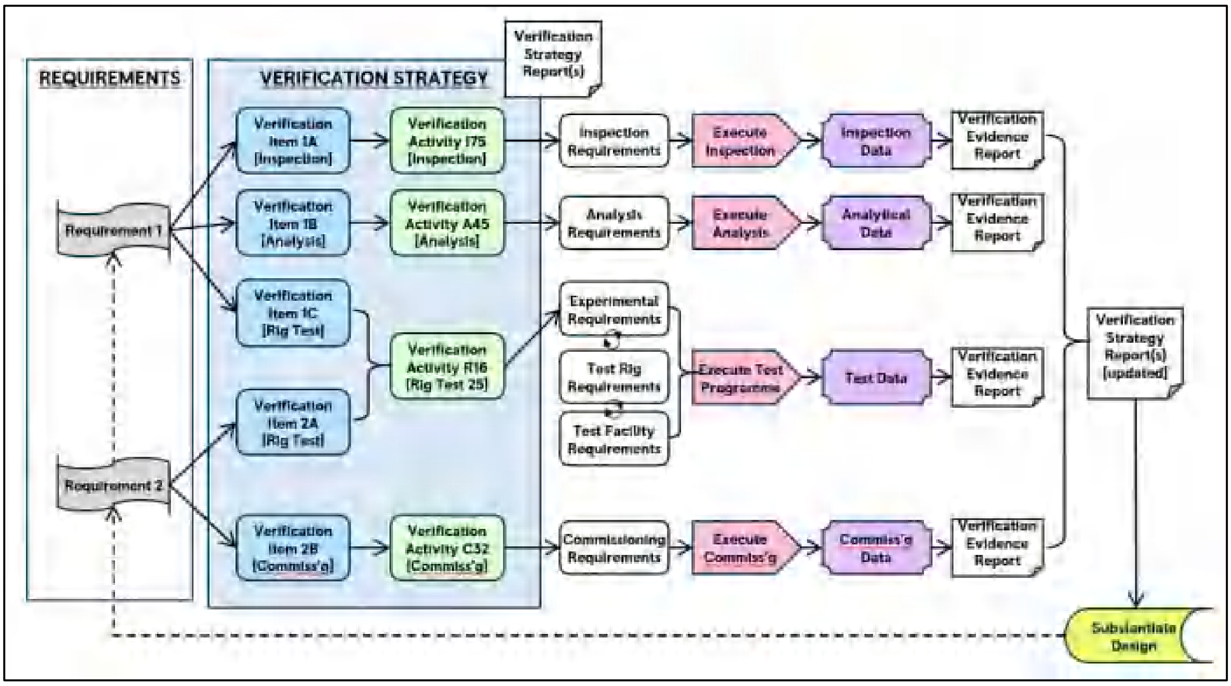

Figure 1.3-1: Structured Verification Process Flow

Evidence

Evidence is gathered that could either provide the design rationale (i.e., optioneering in support of the design definition), or provide the verification that a requirement has been met (i.e., test rig results in support of a verification strategy). It may include supporting reports, assessments, performance analyses, calculations, models, decision records etc., and is referenced to from the relevant DOORS modules. This provides the compliance evidence for the E3S Case to support substantiation of E3S requirements.

1.3.5 Design Decision Making Process

For engineering activities on the RR SMR programme, the reasoning behind all design decisions is recorded to aid traceability within the design process and support demonstration of ALARP, BAT, Secure-by-Design and Safeguards-by-Design. This includes details of the alternative options that were considered, the decision-making method used, the evaluations made during decision making, the criteria that were considered, and who approved the decision. The design decision-making process is summarised in E3S Case Chapter 24: ALARP Summary, Reference [13].

1.3.6 E3S Process

The process steps to embed E3S requirements in the design are illustrated in Figure 1.3-2, noting this is an iterative process with feedback loops throughout that are not shown.

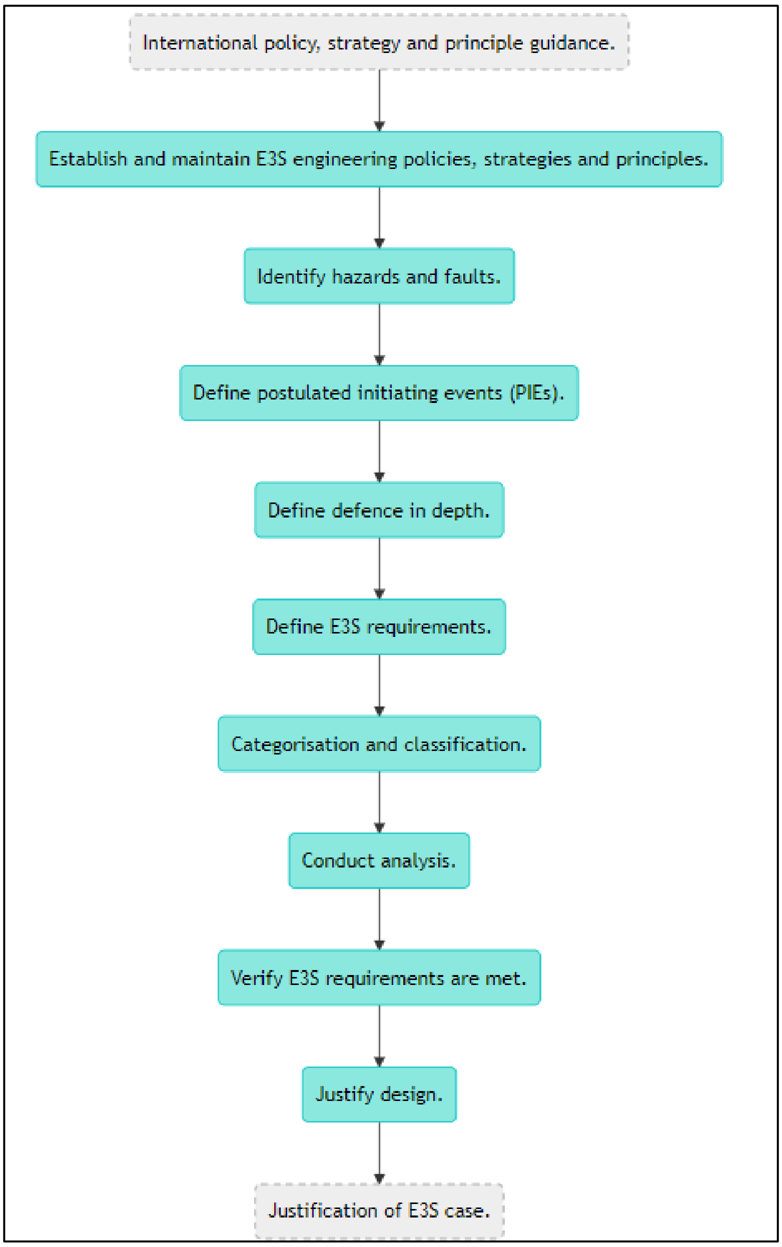

Figure 1.3-2: Combined E3S Process for RR SMR

1.3.7 E3S Design Principles

To achieve the fundamental E3S objective 'to protect people and the environment from harm', a hierarchical decomposition of a set of E3S Design Principles have been established, Reference [5], which provide a framework against which the design is evaluated and developed.

The E3S Design Principles have been derived based on an extensive and thorough desktop review of UK and international practices for nuclear facilities, including: IAEA principles and safety guides; Western European Nuclear Regulators' Association (WENRA) Safety Reference Levels and associated guidance; European Utility Requirements (EUR); Nuclear Industry Safety Directors Forum guidance, ONR Safety Assessment Principles (SAPs), SyAPs and GDA Technical Guidance; and EA Regulatory Guidance.

Details of the principles, approaches, methods, and requirements that govern the E3S design and analysis of the RR SMR to achieve the fundamental E3S objective are presented in E3S Case Chapter 3: E3S Objectives & Design Rules for SSCs, Reference [14]. Compliance against the E3S Design Principles is demonstrated through implementation of these methods across chapters of the E3S Case. Furthermore, detailed methodologies will be developed based on RGP and justified within relevant chapters.

1.4 Plant Layout

The RR SMR general site layout at RD5 design stage is illustrated in Figure 1.4-1, with the Reactor Island [R01] plant layout illustrated in Figure 1.4.2. Further details including principles for development and interfaces/boundaries are outlined in the PCD Site Layout Report, Reference [15].

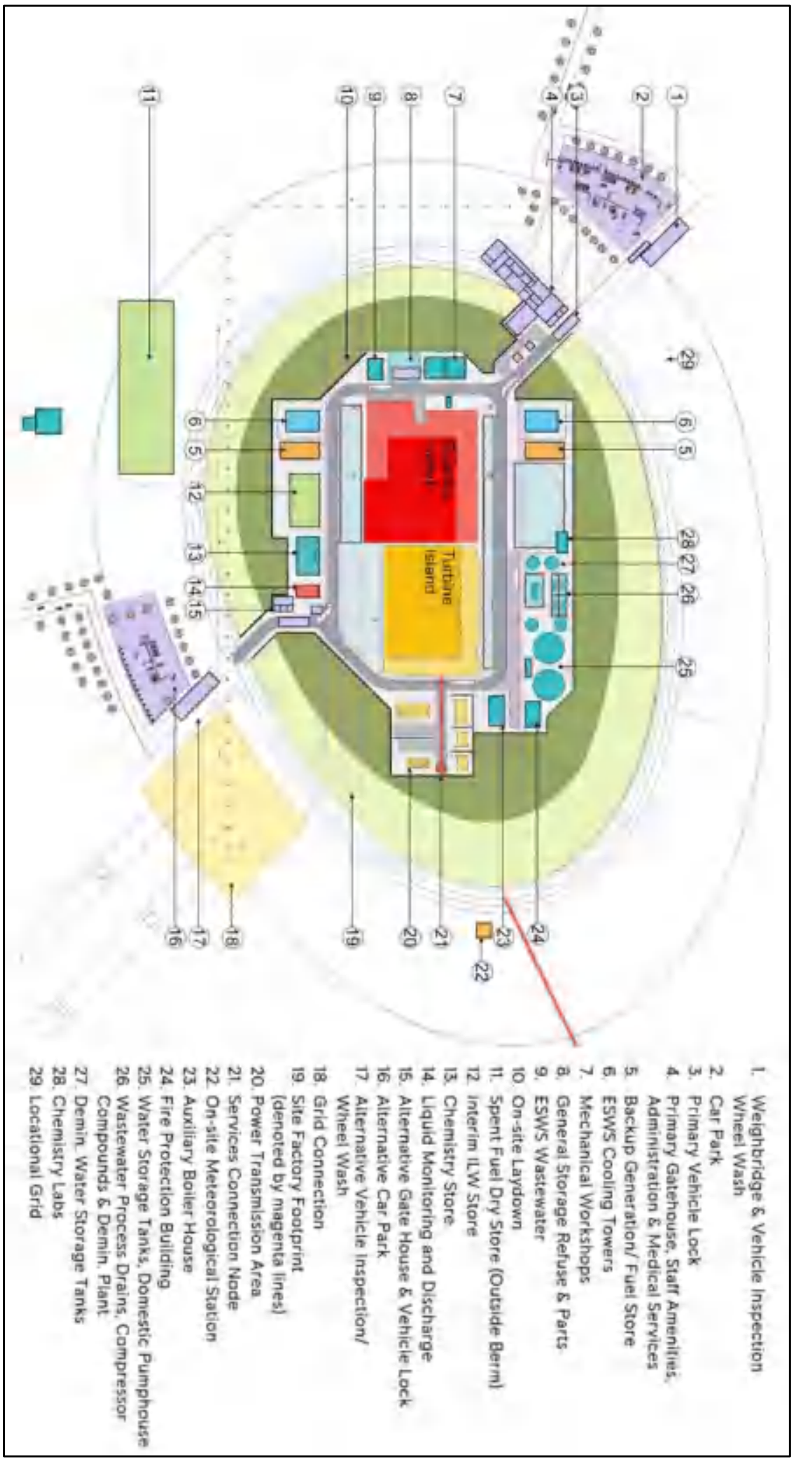

Figure 1.4-1: RR SMR Site Layout

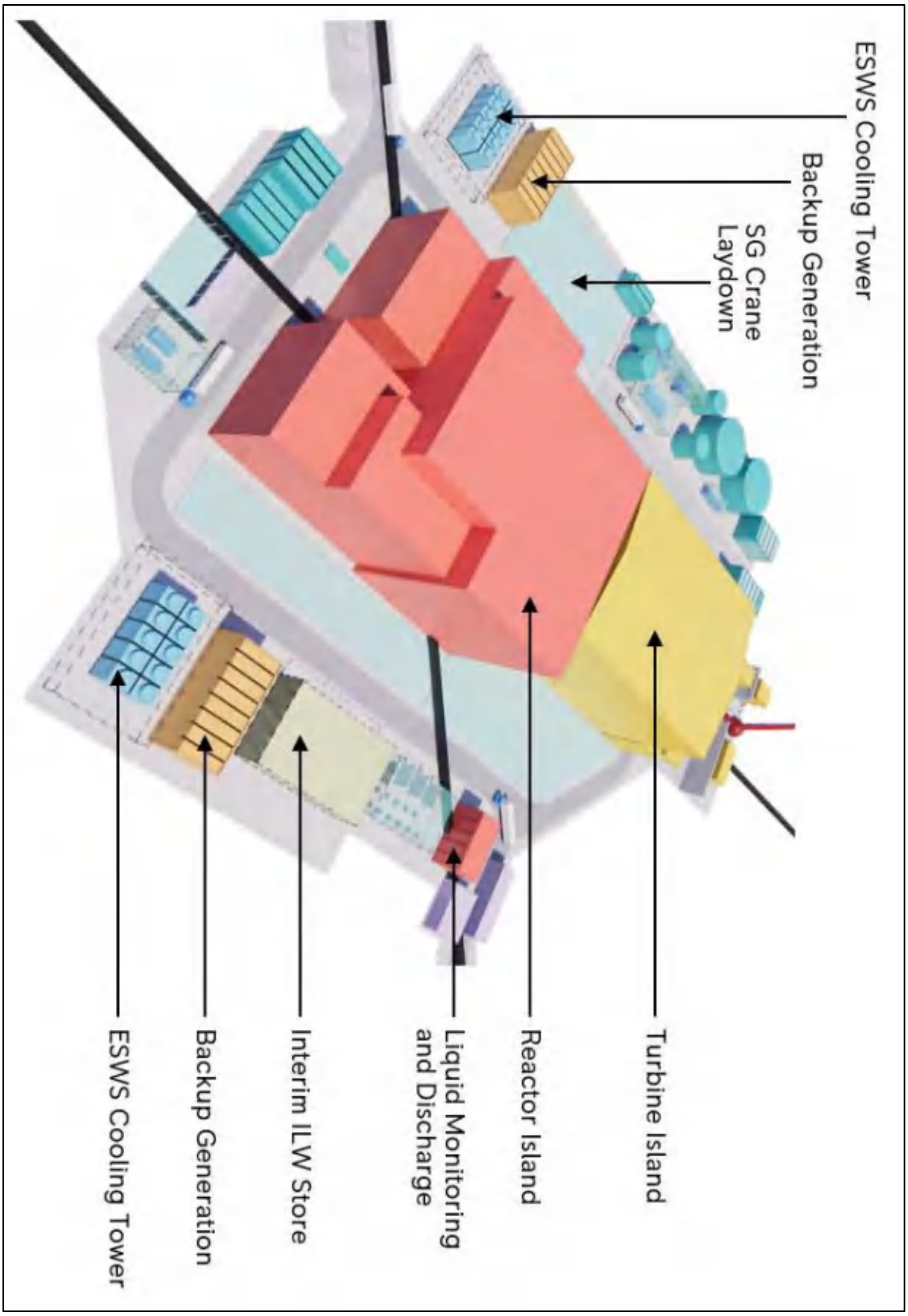

Figure 1.4.2: Reactor Island Layout

1.5 General Plant Description

1.5.1 RR SMR Overview

The RR SMR design is based on an optimised and enhanced use of proven technology, with a single unit, three-loop PWR providing a target power output of 470 MWe.

The following sub-sections provide a summary of the RR SMR technical parameters, and a summary of each of the 'islands' that comprise the power station.

Major Technical Parameters

The major technical parameters of the RR SMR are summarised in Table 1.5-1, with additional technical parameters summarised in Table 1.5-2.

Table 1.5-1: RR SMR Major Technical Parameters

Feature	Parameter	Unit
Thermal Capacity	1358	MW_{th}
Net Electrical Power	470	MW_e
Design life for Non-Replaceable Components	60	Years
Fuel Cycle	18	Months
Fuel Assembly Average Discharge Burnup	50-60	GWd/te
Fuel Assembly Maximum Discharge Burnup	62	GWd/te
Limit for Lead Pin Burnup	62	GWd/te
Control Rod Number	113	-
Spent Fuel Storage Capacity	160	Assemblies
Outage Duration	To Be Confirmed (TBC)	-
Extended Low Power Operation	TBC	-
Load Follow Range	50-100	% of net rated output
Load Follow Variation Range	3-5	% of net rated output/min
Turbine Island gross / net efficiency target – cold heat sink conditions	38.60	%
Turbine Island gross / net efficiency target – hot heat sink conditions	TBC	-
Overall Capacity Factor	>90	%
General Plant Characteristics	Single Unit	-

Table 1.5-2: RR SMR Additional Technical Parameters

Feature	**Parameter**	**Unit**
Plant Footprint	40,000	m^2
Coolant / Moderator	Light Water	-
Primary Circulation	Forced Circulation	-
System Pressure	15.5	MPa
Main Reactivity Control Mechanism	Control Rods	-
RPV Height	7.9	m
RPV Diameter	4.2	m
Coolant Temperature, core outlet	325	°C
Coolant Temperature, core inlet	295	°C
Power Conversion Process	Indirect Rankine Cycle	-
Passive Safety Features	Yes	-
Active Safety Features	Yes	-
Fuel Type / Assembly Array	Industry standard Uranium Oxide fuel in 17x17 array	-
Fuel Active Length	2.8	m
Fuel Assembly Number	121	-
Fuel Enrichment (Maximum)	4.95	%

Reactor Island [R01]

The Reactor Island [R01] includes the systems that form the reactor, transfer, and storage of new and used fuel, and any associated nuclear auxiliary systems. The purpose of Reactor Island [R01] is to use the heat from a controlled nuclear fission reaction to generate steam, which is then passed to the Turbine Island [T01]. Reactor Island [R01] includes the Reactor Plant [J], Handling of Nuclear Equipment [F] and Nuclear Auxiliary Systems [K].

The Reactor Plant [J] comprises:

1. Reactor System [JA], containing the systems and components that generate and transfer nuclear heat in a safe, controlled manner. It comprises a RPV [JAA] of very high reliability, an Integrated Head Package (IHP) [JAB] to facilitate core loading and core unloading, and RPV Internals [JAC10] to hold the fuel assemblies in place. Descriptions of the associated systems and components are summarised in E3S Case Chapter 4: Reactor (Fuel & Core), Reference [16]

2. Reactor Reactivity Control Systems [JD], comprising the Scram Function [JD01], which uses control rods to provide solid neutron absorption during normal operating modes and rapid shutdown in the event of a fault, and the independent and diverse Alternative Shutdown Function (ASF) [JD02], which injects potassium tetraborate into the Reactor System [JA] at high pressure during fault conditions. Descriptions of the associated

systems are summarised in E3S Case Chapter 6: Engineered Safety Features, Reference [17]

3. RCS [JE], comprising a three-loop system each with a Steam Generator (SG), associated pipework and a single pump. The configuration of the SG pipework and pump layout in each loop ensures a robust thermal driving head for natural circulation flow in fault conditions. The system also contains pressurising system with a pump induced spray configuration and associated pressure relief system. Descriptions of the associated systems and components are summarised in E3S Case Chapter 5: Reactor Coolant System & Associated Systems, Reference [18]

4. Reactor Plant Containment Systems [JM], providing the systems that ensure the Confinement of Radioactive Material (CoRM) safety function in normal and fault conditions. Descriptions of the associated systems are summarised in E3S Case Chapter 6: Engineered Safety Features, Reference [17]

5. Reactor Heat Removal Systems [JN], containing the systems that provide decay heat removal to provide the Control of Fuel Temperature (CoFT) in response to fault conditions. This includes the ECCS [JN01], which is the principal means of providing passive decay heat removal in the event of an intermediate or large Loss of Coolant Accident (LOCA), and the Passive Decay Heat Removal System [JN02], which provides decay heat removal in the event of an intact circuit fault. Descriptions of the associated systems are summarised in E3S Case Chapter 6: Engineered Safety Features, Reference [17]

6. Reactor Island C&I [JQ][JR][JS][JT][JY], containing the nuclear C&I systems for control, monitoring and protection of SSCs delivering a nuclear safety function. Descriptions of the C&I systems are summarised in E3S Case Chapter 7: Instrumentation & Control, Reference [19]

The Handling of Nuclear Equipment [F] includes those systems that cover the fuel route from initial receipt of new fuel to final disposal, summarised in E3S Case Chapter 9A: Auxiliary Systems, Reference [20].

The Nuclear Auxiliary Systems [K] comprises of auxiliary systems supporting Reactor Plant [J] operations, including:

1. Component Cooling Systems [KA] and associated coolant treatment and sampling, to transfer heat from reactor components to the ultimate heat sink in a safe manner. Descriptions of the associated systems are summarised in E3S Case Chapter 9A: Auxiliary Systems, Reference [20]

2. Nuclear Trace Heating System [KH], summarised in E3S Case Chapter 6: Engineered Safety Features, Reference [17]

3. Heating, Ventilation and Air Conditioning (HVAC) systems [KL], summarised in E3S Case Chapter 9A: Auxiliary Systems, Reference [20]

4. Solid Waste Treatment [KM], Liquid Waste Treatment [KN], Gaseous Waste Treatment [KP] and Collection & Drainage Systems [KT summarised in E3S Case Chapter 11: Management of Radioactive Waste, Reference [21]

Turbine Island [T01]

The Turbine Island [T01] provides the link between the Reactor Island [R01] where steam is generated, and the electrical connections where generated electricity is provided to the power grid. The primary equipment in Turbine Island [T01] is the steam turbine and generator arrangement, where the mechanical energy of steam is converted into electrical energy. The Turbine Island [T01] includes the Steam, Water, Condensate System [L] and Main Turbine Generator System [M].

The main systems within the Steam, Water, Condensate Systems [L] include:

1. Feedwater System [LA], Steam System [LB], Condensate System [LC], and Condensate Polishing System [LD], summarised in E3S Case Chapter 10: Steam & Power Conversion Systems, Reference [22]

2. Emergency Feedwater System [LJ], which provides an independent feedwater provision following loss of main feedwater due to a fault, summarised in E3S Case Chapter 6: Engineered Safety Features, Reference [17]

The Main Turbine Generator System [M] will be housed within a dedicated turbine hall along with other turbine equipment. Its purpose is to convert steam into mechanical energy through centrifugal action. The key systems include the Steam Turbine System [MA], the Generator System [MK], and Auxiliary Systems [MU], summarised in E3S Case Chapter 10: Steam & Power Conversion Systems, Reference [22].

A high-level schematic for the Turbine Island [T01] is illustrated in Figure 1.5-1.

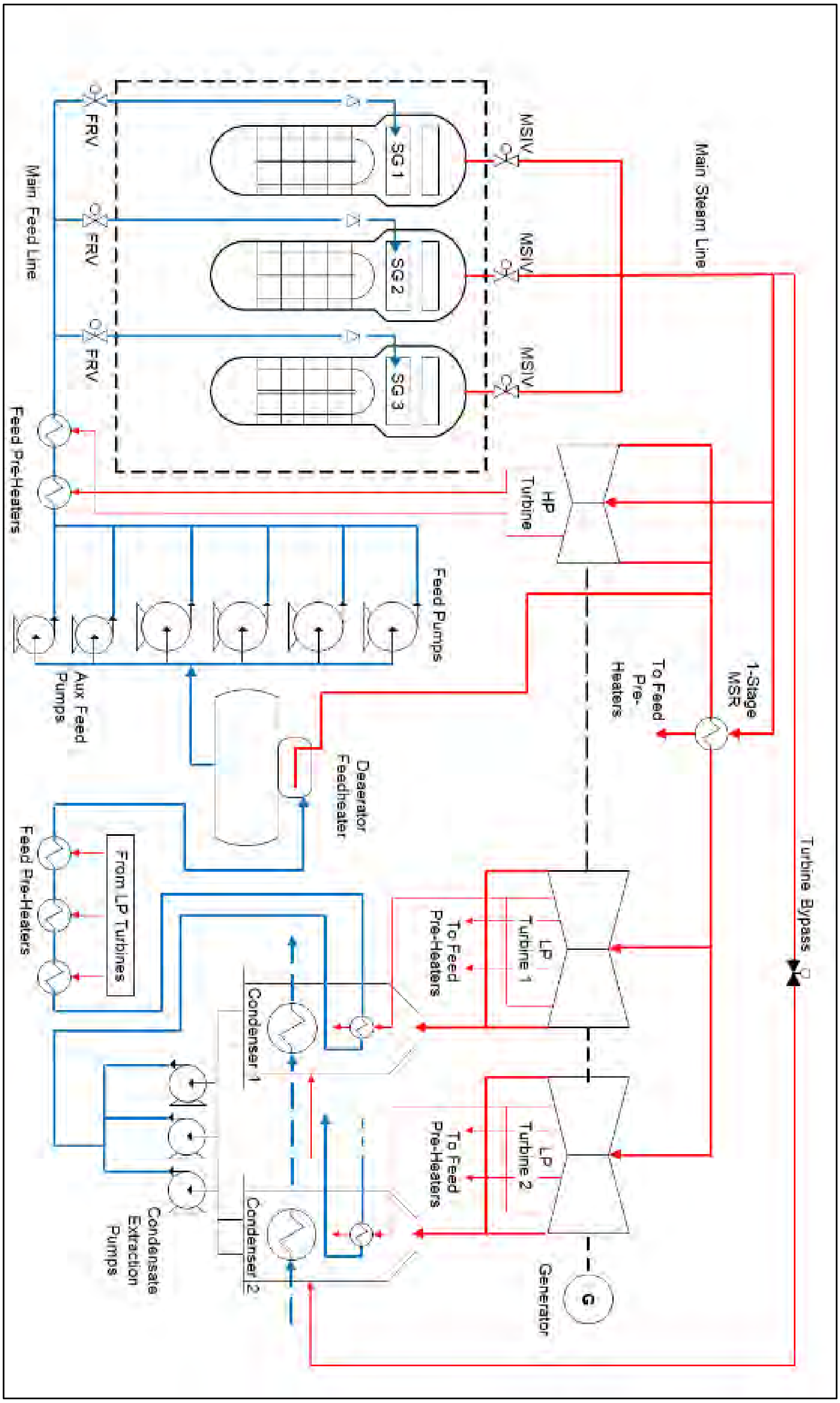

Figure 1.5-1: High-Level Turbine Island [T01] Schematic

Cooling Water Island [C01]

Cooling Water Island [C01] provides the primary means of removing heat from the power station, passing it to the ultimate heat sink, comprising the Cooling Water Systems [P] including:

1. Main Cooling Water System (MCWS) [PA]
2. Auxiliary Cooling & Make-up System (ACMS) [PE]
3. Essential Service Water System [PB]
4. Turbine Island Closed Cooling Water System [PG]
5. Common Systems for the Cooling Water Systems [PU]

Descriptions of the associated systems are summarised in E3S Case Chapter 9A: Auxiliary Systems, Reference [20].

Cooling Water Island [C01] relies on the external environment to provide a means of cooling. Rolls-Royce SMR's aim is to provide a standardised product that can operate on a wide range of sites through minimal adaption and optimisation of a single design, where such sites potentially including inland, lake, river, estuarine and coastal locations. An indirect system at a coastal site has been selected as the baseline design, noting the final solution will be site-specific.

Balance of Plant [B01]

The Balance of Plant [B01] systems support the availability of the power station by providing a range of support functions to the rest of the plant, which are of low safety significance but important to maximising output and plant efficiency and minimising environmental impacts. This includes the provision of chemicals, utilities, water and sampling services, and general storage areas. The facilities include the Water Supply, Disposal, Treatment System [G], Auxiliary Systems [Q], Storage Systems [V] and Ancillary Systems [X].

The Balance of Plant [B01] systems in scope of GDA are summarised in E3S Case Chapter 9A: Auxiliary Systems, Reference [20].

Electrical, Control and Instrumentation Systems [E01]

Electrical, Control and Instrumentation Systems [E01] includes systems relating to grid connection and intra-site electrical distribution, including the Grid Transmission System [A], Electrical Power System [B], Generator Transmission Main Connection [MS] and Equipotential Bonding System [XF].

The Electrical Power System [B] includes the provision of emergency power supplies, which incorporates significant defence in depth to provide backup power in the event of Loss of Off-site Power (LOOP) and Station Blackout (SBO) faults. It also includes non-nuclear C&I systems, covering control, monitor and protection functions (it excludes nuclear C&I, which is part of Reactor Island [R01]).

Descriptions of electrical power systems are summarised in E3S Case Chapter 8: Electrical Power, Reference [23], and C&I systems are summarised in E3S Case Chapter 7: Instrumentation & Control, Reference [19]

Civil, Structural & Architectural Systems [CIV]

Civil, Structural & Architectural Systems [CIV] provide the physical structures which house, support and protect all other systems across the power station. This includes the base isolation system delivered by the aseismic bearings, and the hazard shield providing protection from external hazards.

Descriptions of the associated structures for the power station are summarised in E3S Case Chapter 9B: Civil Structures, Reference [24].

1.5.2 Construction & Build Certainty

The RR SMR is designed as a modular and standardised power station product. This means that each RR SMR is substantively the same as the others; so far as is possible within the constraints of site-specific geography. To achieve this design outcome, the RR SMR civil design is split into two: groundworks/foundations, and power station modules and buildings.

The groundworks and foundations supporting the RR SMR are necessarily bespoke and matched to local site conditions. They support an aseismic bearing, upon which the critical modules and buildings reside.

The modules and buildings are identical from site to site and consist of factory produced modules and components that are assembled into a functioning RR SMR on-site.

During construction, most Rolls-Royce SMR structures and equipment will be enclosed within a 'site factory', which minimises the impact of factors such as adverse weather conditions on programme schedules, whilst enabling 24/7 working. The site factory provides both isolation of the site from the environment, and isolation of the environment from the site.

1.5.3 Operating Philosophy

Modes of Operation

The modes of operation of the RR SMR are defined as:

1. Mode 1 – Power Operation
2. Mode 2 – Low Power
3. Mode 3 – Hot Standby
4. Mode 4A – Hot Shutdown – Steaming
5. Mode 4B – Hot Shutdown – Non-Steaming
6. Mode 5A – Cold Shutdown (Pressurised)
7. Mode 5B – Cold Shutdown (Depressurised)

8. Mode 6A – Refuelling with Reduced Water Level above Fuel

9. Mode 6B – Refuelling with Water Level above Fuel at Nominal Full

The reactor is safely shutdown when the control rods are fully inserted on the transition from Power Operations (Modes 1 and 2) to Shutdown Operations (Modes 3-6). The reactor remains shutdown in Modes 3-6 and on the return to Power Operations the control rods are first raised in Mode 2. The RCS temperature and pressure for each operating mode is presented in Figure 1.5-2.

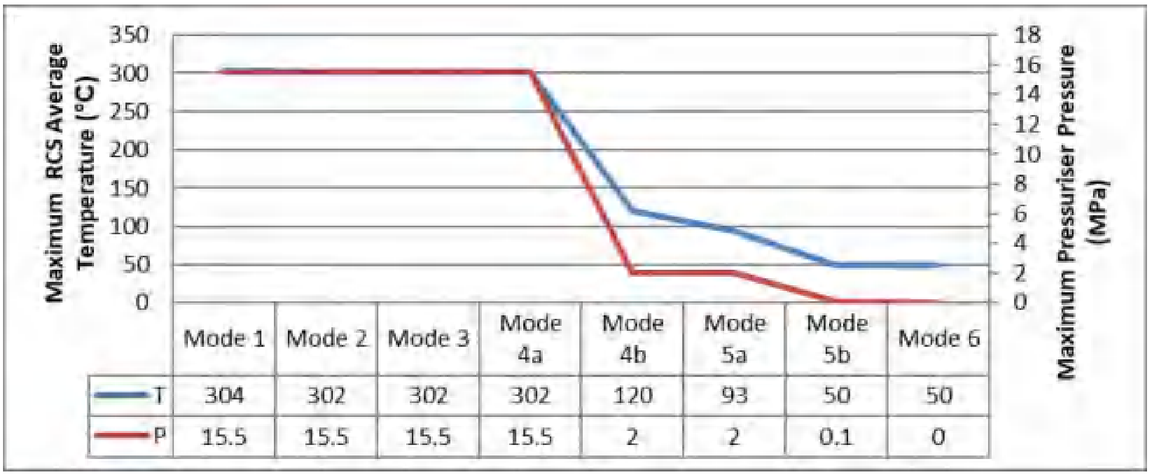

Figure 1.5-2: Operating Mode Parameters

There will be a clear distinction between each of these modes for Reactor Island [R01], with changes in RCS temperature, pressure and alignment or release of systems. Other areas may be required to provide different functions to Reactor Island [R01] across each of the modes.

The means by which the plant and operator maintain control of key functions across the operating modes are outlined in further detail in E3S Case Chapter 13: Conduct of Operations, Reference [25].

RR SMR Uses

The RR SMR has the potential to be integrated with and support:

1. Electricity generation including baseload, load follow, frequency response and provision of other services to the power grid

2. Combined Heat and Power (CHP) – grid electricity plus steam off-take, for e.g., district heating

3. E-fuels:

    a. Hydrogen only via ‘high’ temperature solid oxide electrolysis with steam off-take

    b. As (a) but with electricity to off-grid synthetic fuel plant (e.g., Fischer-Tropsch process)

    c. ‘Pure’ electricity for Hydrogen production

d. Carbon capture for E-fuels

4. Desalination – electricity and/or steam off-take to desalination plant

The RR SMR is designed for full compliance with the UK Grid Code, Reference [26], noting capabilities will be more flexible than the minimum required by the Grid Code, including:

1. Frequent load following between 50% and 100% power at a rate of 3-5% per minute, and a design target to allow operation at lower power levels (e.g., 20%)

2. House load operation – stable operation for at least two hours supplying only the power station's house load. This enables the plant to 'trip to house load' in the event of grid disturbance, rather than shutting down, which allows for a rapid reconnection to the grid after the disturbance

3. Islanded operation – supplying the power station's house load and a small section of grid, subject to operating constraints

RR SMR Lifecycle

The RR SMR has a planned lifetime of approximately 60 years, with refuelling and maintenance required periodically. Refuelling is completed when the reactor is offline, i.e., not producing energy. The frequency and duration of these 'outages' will be minimised as far as is safe and practicable to optimise the availability of the RR SMR.

RR SMR Control

Monitoring and control of the RR SMR will be centralised within the Main Control Room (MCR), located within Reactor Island [R01]. From here, the operators monitor the reactor response to changes in turbine load, driven by demand from the facility which the RR SMR is supporting (e.g., the electricity grid).

If the MCR is uninhabitable (e.g., due to fire), then the operators can transfer to the Supplementary Control Room (SCR). The SCR is also located within Reactor Island [R01], such that a single incident should not threaten both control rooms (e.g., with appropriate separation and segregation) but also to allow safe transfer of personnel. The SCR will include monitoring and control of safety related systems, to ensure a safe state is achieved and maintained.

Fleet Approach

The RR SMR is a single design, deployable across regions and customers without significant design modifications. One of the benefits which this approach delivers is the potential to share data and knowledge across the RR SMR operators, supporting optimisation of various aspects such as operations, maintenance, or staffing.

1.6 Comparison with other Plant Designs

The RR SMR is a FOAF design and not based on a currently operating reference plant. The design is however fundamentally based on proven PWR technology, using industry standard uranium fuel. The RR SMR programme commenced in 2016, with key design principles established early that were driven by market requirements and lessons learnt from previous nuclear power plant programmes. This led to the 20 key design objectives being established for RR SMR, which have been consistently applied as the basis for design optioneering (see Section 1.3.2).

The initial reference design baseline, RD1, was established in 2016 with limited maturity, reflecting fundamental decisions such as the selection of PWR technology and a boron-free chemistry regime.

The design definition for the RR SMR has significantly increased in maturity since RD1 through extensive optioneering and design decisions undertaken in line with ALARP and BAT, with progressive design baselines established. RD5 was established in June 2022, which forms the basis for Issue 1 of the E3S Case.

The main innovations for RR SMR are in the fabrication and construction of the modular nuclear plant, incorporating use of proven techniques and RGP from other industries. In comparison to existing PWR power stations, the RR SMR at RD5 does incorporate notable innovations that provide benefits with respect to E3S, including:

1. Passive and diverse heat removal systems (the ECCS [JN01] and Passive Decay Heat Removal (PDHR) [JN02]) to provide decay heat removal in response to fault conditions, each with significant internal redundancy, and with no reliance on essential services supplied from on-site mobile equipment for 72 hours or from off-site for 7 days

2. Boron-free chemistry, with full shutdown margin provided by the control rods alone, which allows for a simplified design with a reduction in human error induced faults, and eliminates risks associated with boric acid, boron dilution faults, and the environmental impact of boron discharge. It also enables the use of potassium hydroxide (KOH) as the pH raiser, rather than lithium hydroxide (LiOH) that is used in conjunction with boric acid in traditional PWRs, offering potential benefits such as mitigation of fuel cladding corrosion and reduction in the tritium source term

3. A base isolation system, which reduces the seismic hazard for the Reactor Island [R01] and adjacent safety significant structures. By means of an aseismic bearing, the base isolation provides attenuation of the horizontal seismic ground motion to limit the peak acceleration transmitted to the structures located above it

4. A forced draught cooling system, which is adaptable to different cooling water constraints such that the RR SMR is deployable across a wide range of sites

5. Emergency blowdown relies on a mechanical valve design that provides reactor coolant relief in conditions where ECCS [JN01] is demanded. The design of this valve practically eliminates a spurious opening of the blowdown line fault and minimises the safety requirements placed onto the C&I systems

1.7 Summary of Environmental Aspects

1.7.1 GDA Information Requirements

This section provides a summary of key information contained in E3S Case Chapters 26 to 31 that form part of the GER. Table 1.7-1 maps the 'General information about the RP and the design' requested in the GDA guidance to RPs to the relevant chapters where such information is presented.

Table 1.7-1: Map of Information Requirements to E3S Case

GDA Information Requirements	Chapter of E3S Case
Details about the RP, including its company structure and its experience of reactor design and plants in service are provided	• E3S Case Chapter 1
A simple, outline description of the design including schematic diagrams is provided	• E3S Case Chapter 1 • E3S Case Chapter 25
A brief history of the design of traditional PWR and the main design changes from this plant	• E3S Case Chapter 1
Identification of discharge points to the environment for gaseous and aqueous radioactive wastes	• E3S Case Chapter 1 • E3S Case Chapter 25 • E3S Case Chapter 29 • E3S Case Chapter 11
A summary of the proposed disposals of radioactive waste and their potential impact on members of the public and non-human species at the generic site	• E3S Case Chapter 1 • E3S Case Chapter 26 • E3S Case Chapter 29 • E3S Case Chapter 30
A summary of the proposed conventional environmental impacts	• E3S Case Chapter 1 • E3S Case Chapter 31
A description, and the characteristics, of the generic site (or sites) that the RP will use for its assessment of radiological and conventional impacts on people and the environment	• E3S Case Chapter 1 • E3S Case Chapter 2

1.7.2 Generic Site Description

The GSD describes the characteristics of a generic site for purposes of the GDA, including associated location parameters, that will form the basis for assessing radiological and conventional impacts on people and the environment, predicted to arise from operating the RR SMR. The generic site is assumed to be a rural coastal site, set on a flat plain with no freshwater bodies within or close to the site, and no freshwater courses traversing the site. The GSD also assumes that there are no designated sites or species of conservation importance within or close to the site, nor is there contamination of the ground or groundwater.

Geographical parameters and site characteristics defined in the GSD are typical of UK coastal locations, where the RR SMR plant is assumed to be situated for purposes of the GDA, and include information such as:

1. Meteorological and other parameters which affect the dispersion and depositions of gaseous discharges from the RR SMR

2. Hydrographic and other parameters which affect the dispersion of aqueous discharges from the RR SMR

3. The habitation of local exposure groups and their food source locations, relative to the RR SMR plant

4. Food consumption rates and other human habits data

5. A list of reference organisms assumed to be present in the vicinity of the site (for the assessment of radiological impacts on non-human biota)

Details of the GSD are presented in E3S Case Chapter 2: Generic Site Characteristics, Reference [27].

1.7.3 Radioactive Waste Management Arrangements

An Integrated Waste Strategy (IWS) outlining the proposed approach for managing conventional and radioactive wastes arising from RR SMR has been prepared. The IWS presents a summary of predicted RR SMR waste inventory, and strategies for managing the different waste streams making up this inventory (including radioactive and conventional wastes in solid, liquid, and gaseous form, and materials that could become waste), and covers all phases of the plant lifecycle.

The IWS also describes how the strategy has been developed and applied in the context of the political, regulatory, and business requirements associated with the operation of new Nuclear Power Plants (NPPs) in the UK.

Further, Rolls-Royce SMR have initiated engagements with the Nuclear Waste Services (NWS) to support the development and assessment of disposability case; to support the demonstration that predicted arisings of higher activity waste and spent fuel can be disposed of in a future Geological Disposal Facility (GDF).

The IWS and disposability assessment form the key inputs into the RWMA. Details of the RWMA are presented in E3S Case Chapter 26: Detailed Description of Radioactive Waste Management Arrangements, Reference [28].

1.7.4 Demonstration of BAT

Application of BAT in the design of the RR SMR is demonstrated in the E3S Case using the CAE approach described in Section 1.1. The application of BAT in the context of the RR SMR design development is framed around four fundamental claims, which seek to demonstrate that the RR SMR design:

1. Eliminates or reduces the generation of radioactive waste
2. Minimises the amount of radioactivity discharged or disposed of to the environment
3. Minimises the volume of radioactive waste disposed to other premises
4. Minimises the impacts on the environment and members of the public from radioactive waste discharged or disposed of to the environment

Details of the approach for, and demonstration of, the use of BAT in the RR SMR design are presented in E3S Case Chapter 27: Demonstration of BAT, which is under development. The BAT methodology and example of the CAE structure for RR SMR are detailed in Reference [29].

1.7.5 Radioactive Effluent Discharges Points

Aqueous radioactive effluent will be discharged via a single discharge line to the cooling water outfall prior to release into the receiving environment. The discharge line will be fitted with flow proportional sampling equipment to monitor the volume of effluents releases and appropriate feature (e.g., valves or similar components) that can be actuated to terminate releases of the liquid effluent if required.

Gaseous radioactive effluent will be discharged to the environment through a main emission stack, likely via an appropriately sized stack at the top of the reactor building, and through a smaller stack located above the turbine building. The design of the gaseous radioactive effluent emission stacks is in development, with the main stack expected to receive residual gases from the Gaseous Waste Treatment System [KPL] and radioactive gaseous effluent from the exhaust of the HVAC system [KL], and the smaller stack expected to discharge gases stripped from the turbine condenser. As the design develops it will be supported by appropriate atmospheric dispersion modelling to ensure that the stack is optimised to minimise the impact of discharges on people and the environment, consistent with the use of BAT.

Details of the RR SMR radioactive waste treatment systems and associated structures will be presented E3S Case Chapter 25: Detailed Information about the Design (to be developed) and E3S Case Chapter 29: Quantification of Radioactive Effluent Discharges and Proposed Limits, Reference [30], with the demonstration of BAT for these systems and structures presented in E3S Case Chapter 27: Demonstration of BAT (to be developed).

1.7.6 Discharges of Aqueous and Gaseous Radioactive Effluent to the Environment

A preliminary assessment of potential discharges of aqueous and gaseous radioactive effluent from the RR SMR to the environment, under normal operating conditions, has been performed. Annual discharge limits are also proposed for significant radionuclides present in the predicted discharges to the environment. The assessment was performed using available design information and published OPEX data from PWR plants and reflects the current level of maturity of the RR SMR.

Annual discharges of aqueous radioactive effluent predicted to arise from the RR SMR, normalised to 1 GWe are mostly below the average of reported or forecast discharges from comparable PWRs. The normalised annual discharge of gaseous radioactive effluent from the RR SMR is consistent with the average of forecast or reported discharges from other PWR plants, noting early estimates for the discharges of 'other radionuclides' are higher than the reported values. As the design and the methods of estimating these discharges develops through subsequent design phases, these values are anticipated to be equal to or better than the discharges from comparable PWRs.

Details of the quantification of radioactive effluent discharges to the environment, including an overview of the approach, underlying assumptions, parameter values and design information are presented E3S Case Chapter 29: Quantification of Radioactive Effluent Discharges and Proposed Limits, Reference [30].

1.7.7 Prospective Impacts of Radioactive Discharges on Members of the Public and Non-Human Species

An initial assessment of prospective radiological impacts associated with discharges of aqueous and gaseous radioactive effluent from the RR SMR (at proposed annual limits) has been carried out. The assessment was performed using the EA's initial radiological assessment tool, utilising RR SMR PCD design information and the characteristics of a generic site. Conservative assumptions have been made, where necessary, to account for data such as the contribution from direct radiation pathways which is currently unavailable.

The prospective annual dose to a representative member of the public is estimated to be around 12.3μSv/yr, which is well below the source dose constraint of 300μSv/yr. The dose rate to the worst affected non-human organism is estimated at around 0.02μGy/hr, which is significantly less than the screening dose rate of 1μGy/hr and the guideline dose rate of 40μGy/hr.

Further, detailed radiological assessments using appropriate modelling software will be developed in line with the CAE Route Map, Reference [6]. Details of the initial radiological assessment and the proposed detailed radiological assessment are presented in E3S Case Chapter 30: Prospective Radiological Assessment at the Proposed Limits for Discharges and for any On-Site Incineration, Reference [31].

1.7.8 Conventional Environmental Impacts

An appraisal of other environmental regulations and associated environmental impacts has been undertaken, based on the RR SMR design maturity at PCD. The appraisal considered the GDA information requirements for other environmental regulations and included a preliminary review of conventional (i.e., non-radioactive) environmental aspects of the RR SMR in the following topic areas:

1. Water use and abstraction
2. Discharges to surface water
3. Discharges to groundwater
4. Operation of installations (combustion plant and incinerators)

5. Control of Major Accident Hazards Regulations 2015 (COMAH)

6. Fluorinated greenhouse gases and ozone-depleting substances

Each of these topics, and details of the other environmental regulations and conventional environmental aspects, are presented in E3S Case Chapter 31: Conventional Impact Assessment, Reference [32].

1.8 Conclusions

This report presents the introduction to the suite of 33 chapters that comprise the RR SMR E3S Case at the PCD design stage. It outlines the holistic approach to E3S that is adopted for the RR SMR, and the overall structure of the E3S Case that facilitates the demonstration that the fundamental objective 'to protect people and environment from harm' can be achieved at all lifecycle stages of the power station, and demonstrate that risks can be reduced to ALARP, using BAT, and ensuring Secure-by-Design and Safeguards-by-Design.

The E3S Case is being developed alongside the ongoing design programme and will also provide the basis for submissions as part of the GDA regulatory assessment process. A CAE Route Map is being developed to capture the suite of documentation/data that will comprise the full E3S Case, to ensure evidence is being generated that is appropriate to the lifecycle stage and on timescales to meet the GDA programme.

1.9 References

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1.10 Acronyms and Abbreviations

ACMS	Auxiliary Cooling and Make-up System
ALARP	As Low As Reasonably Practicable
ASF	Alternative Shutdown Function
BAT	Best Available Techniques
BSO	Basic Safety Objective
C&I	Control & Instrumentation
C/S	Containment/Surveillance
CAE	Claims, Arguments, Evidence
CDF	Core Damage Frequency
CDM	Construction Design and Management
CDR	Critical Definition Review
CHP	Combined Heat and Power
CoFT	Control of Fuel Temperature
COMAH	Control of Major Accident Hazard Regulations 2015
CoRM	Confinement of Radioactive Material
DiD	Defence in Depth
DOORS	Dynamic Object-Oriented Requirements System
DRP	Design Reference Point
E3S	Environment, Safety, Security and Safeguards
EA	Environment Agency
ECCS	Emergency Core Cooling System
EMIT	Examination, Maintenance, Inspection and Testing
EMP	Engineering Management Plan
ESWS	Essential Service Water System
EUR	European Utility Requirements
FCD	Final Concept Definition
FOAF	First of a Fleet
FSF	Fundamental Safety Function

GB	Great Britain
GDA	Generic Design Assessment
GDF	Geological Disposal Facility
GER	Generic Environment Report
GSD	Generic Site Description
GSR	Generic Security Report
HF	Human Factors
HVAC	Heating, Ventilation and Air Conditioning
IAEA	International Atomic Energy Agency
IEC	International Electrotechnical Commission
IHP	Integrated Head Package
ILW	Intermediate-Level Waste
ISO	International Organization for Standardization
IWS	Integrated Waste System
KR	Key Reference
LOCA	Loss of Coolant Accident
LOOP	Loss of Off-site Power
MCR	Main Control Room
MCWS	Main Cooling Water System
NPP	Nuclear Power Plant
NRW	Natural Resources Wales
NWS	Nuclear Waste Services
OLCs	Operating Limits and Conditions
ONR	Office for Nuclear Regulation
OPEX	Operating Experience
PCD	Preliminary Concept Definition

PCSR	Pre-Construction Safety Report
PDHR	Passive Decay Heat Removal
PIE	Postulated Initiating Event
PSA	Probabilistic Safety Assessment
PWR	Pressurised Water Reactor
RCS	Reactor Coolant System
RD	Reference Design
RDS-PP	Reference Design System – Power Plants
REDV	Requirements, Evidence, Design Definition, Verification and Validation
RGP	Relevant Good Practice
RI	Regulatory Issue
RO	Regulatory Observation
RP	Requesting Party
RPV	Reactor Pressure Vessel
RQ	Regulatory Query
Rolls-Royce SMR	Rolls-Royce Small Modular Reactor (Organisation)
RR SMR	Rolls Royce Small Modular Reactor (Design)
RWMA	Radioactive Waste Management Arrangements
SAPs	Safety Assessment Principles
SBO	Station Blackout
SCR	Supplementary Control Room
SDG	Sustainable Development Goals
SFR	Safety Functional Requirement
SG	Steam Generator
SMR	Small Modular Reactor
SOE	Safe Operating Envelope
SQEP	Suitably Qualified and Experienced Personnel
SSC	System, Structure, Component
SV	Structured Verification
SyAPs	Security Assessment Principles
TBC	To Be Confirmed

UK	United Kingdom
UN	United Nations
WENRA	Western European Nuclear Regulators' Association
WoFG	Well-being of Future Generations