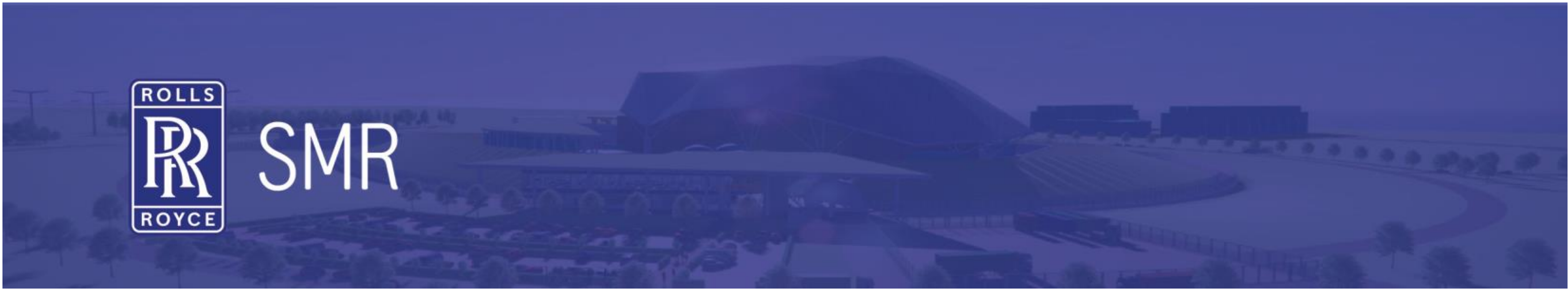


Partner Document Number	Partner Document Issue /Revision	Retention category:
N/A	N/A	A

Title

Approach for Optimisation through the Application of BAT

Executive Summary

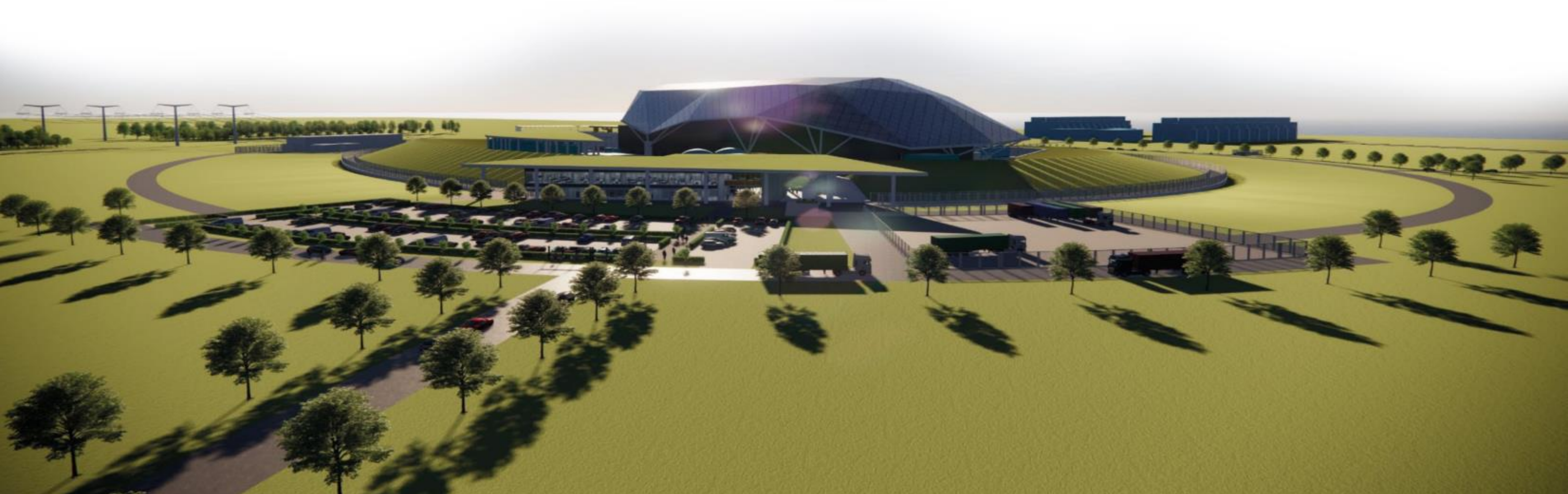
Application of Best Available Techniques (BAT) to prevent the generation, and where this is not possible, minimise the volume and activity of wastes produced, disposed, and discharged and to minimise the consequent impact of such wastes on members of the public and the environment, is a fundamental objective of the Rolls-Royce Small Modular Reactor (RR SMR) and a UK regulatory requirement for all industrial processes.

This document describes a methodology for the optimisation of the RR SMR through the application of BAT during the design stage and describes a proportionate approach for the subsequent demonstration of BAT in the RR SMR design. It draws upon relevant guidance and establishes good practice on the application of BAT within the nuclear industry.

The methodology for gathering and evaluating BAT options has been aligned with, and integrated, into the design decision process for the RR SMR to allow a holistic consideration and optimisation of all the key factors influencing design decisions and the approach to demonstrating the application of BAT is structured upon the claims-arguments-evidence model.

The RR SMR key design principles and assessment criteria, explicitly incorporate criterion on environment, safety and security alongside technical feasibility, cost, and market factors. These criteria are aligned with The United Nations Sustainable Development Goals (SDGs) and the goals of the Wellbeing of Future Generations (Wales) Act and have been incorporated into the RR SMR design process through the Decision Record Template.

Development of the RR SMR from an early concept design to a fully developed power station design presents a unique opportunity to develop a design that embeds the principles of ALARP, BAT and Secure-by-Design at a fundamental level from the outset. These principles are consistent with global good practice and incorporating them into the RR SMR design will improve its compliance with regulatory requirements across different jurisdictions around the globe.



Contents

Tables

Figures

1 Introduction

1.1 Background

1.1.1 Rolls-Royce Small Modular Reactor Limited (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.

1.1.2 One of the key objectives of the RR SMR is to ensure adequate protection of people and the environment from harm at all lifecycle stages of the power station. This objective is consistent with the fundamental principle of reducing risks to levels that are As Low as Reasonably Achievable (ALARA) using Best Available Techniques (BAT).

1.1.3 This report describes the methodology adopted by Rolls-Royce SMR to optimise, and demonstrate that, the environmental performance of the RR SMR, and the potential impacts on people and the environment, predicted to arise from the operation of the RR SMR, have been minimised.

1.1.4 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. The methodology takes due cognisance of applicable regulatory requirements and associated guidance, as well as Relevant Good Practice (RGP).

1.2 Holistic Approach to Optimisation

1.2.1 The requirements to:

1. Ensure that the risk and subsequent dose to workers and other persons affected by an activity involving the use of radioactivity has been reduced So Far As Is Reasonably Practicable (SFAIRP) or to levels that are As Low As Reasonably Practicable (ALARP).
2. Use BAT to minimise the impacts on members of the public (and the environment) arising from radioactive substance activities (and other industrial processes) to levels that are ALARA, and
3. Ensure a secure design from theft, sabotage, compromise of sensitive material and protection against diversion of Nuclear Material (NM) from peaceful uses

are fundamental precepts underlying the United Kingdom (UK) nuclear licensing and environmental permitting legislation and need to be effectively demonstrated.

These requirements seek to ensure that nuclear facilities and associated processes and activities are optimised to achieve maximum protection of workers and members of the public until such a point that the benefits of implementing further protection measures becomes grossly disproportionate to the cost of doing so.

1.2.2 The evaluation of ALARP, BAT and Secure-by-Design essentially involve the same process of optioneering i.e., identifying possible options, considering benefits and disadvantages of all potential viable options, making informed judgement to identify the preferred option, and then optimising the preferred solution.

1.2.3 It is noted that BAT has a wider remit and requires that ALARP, safety, security and other factors such as socio-economic are all considered alongside environment factors to determine BAT option.

1.2.4 Traditionally ALARP, BAT and Secure-by-Design have been considered independently of one another, probably stemming from the fact that the requirements to demonstrate the application of these precepts are mandated under separate regulatory frameworks. However, there is increasing cognisance of the synergies between these principles and of the benefits of integrating them to achieve rounded optimisation of nuclear facilities and operations.

1.2.5 Development of the RR SMR from an early concept design to a fully developed power station design presents a unique opportunity to develop a design that embeds the principles of ALARP, BAT and Secure-by-Design at a fundamental level into the design process from the outset. These principles are consistent with global good practice and incorporating them into the RR SMR will improve its compliance with regulatory requirements across different jurisdictions around the globe.

1.2.6 Whilst the RR SMR is a First of a Kind (FOAK) design, it is an adaptation of existing Pressurised Water Reactor (PWR) technology. It therefore stands that meaningful comparisons can be made with, and that appropriate feedback and Operational Experience (OPEX) can be obtained from, existing PWR power stations, with due regard to the enhancements embedded in the RR SMR. Thus, where appropriate, the demonstration of BAT will include an account of 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.

1.2.7 It is also recognised that being a FOAK design, the RR SMR presents opportunities to incorporate BAT considerations into the design decision process, to a greater extent than previous nuclear power plants. It is therefore intended that the approach described in this Section integrates into, and forms part of, the overall design development and decision-making process, alongside ALARP and Secure-by-Design considerations.

1.2.8 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 will be 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.

1.3 Scope

1.3.1 The methodology presented in this report is intended to inform the optimisation of, and support the design decisions for, all physical Structures, Systems and Components (SSCs) within the Reactor Island (R01), Turbine Island (T01), Cooling Water Island (C01), Balance of Plant (B01) Electrical, Control & Instrumentation [E01] and Civil Structures (CIV) and also how the optimisation of the RR SMR will be demonstrated.

1.3.2 It is recognised that whereas BAT associated with some conventional (i.e., non-radioactive) SSCs such as large combustion plants and industrial cooling systems are clearly defined in BAT References (BREFs) and BAT Conclusions (BATC) documents. There are several SSCs in the RR SMR conventional islands (T01, C01, B01) and CIV for which there are no established BAT positions. The methodology presented in this document has therefore been developed to support the optimisation of SSCs and design decisions that have a bearing on both conventional and radiological environment protection.

1.3.3 The UK Government has set out proposals to develop a UK BAT System, including BATCs for different industrial sectors. Details of the proposals are published on the UK Government website.

1.3.4 In addition to physical SSCs, the methodology incorporates the broader themes of sustainability including:

1. Wider environmental considerations, for example, energy and resource consumption, as well as the generation and disposal of conventional waste; and

2. Socioeconomic considerations, such as potential impacts on the well-being of members of the public, affordability and impact on implementation of RR SMR.

1.3.5 The methodology has been developed to apply to all phases in the RR SMR product lifecycle. Thus, whilst the focus of the methodology is currently on the design phase, due consideration is given to potential impacts of design options during the operating and decommissioning phases. This would ensure that BAT solutions with evident short-term benefits do not present intractable challenges in the long term.

1.3.6 It is noted that the methodology described in this document focuses on the design optioneering process for identifying and selecting BAT to fulfil specified design requirements. Subsequent optimisation to improve the performance of selected BAT either during latter design phases or the plant operating phase are outside the scope of this document. Either an update to this document or additional methodology document will support the later stages of design. Optimisation will also be addressed as part of the environmental permitting process. Similarly, whilst the identification of Environment Protection Functions (EPFs) and the measures delivering such functions is intrinsically linked to BAT, EPFs have not been expressly considered in this document.

1.4 Design Maturity

1.4.1 The RR SMR is still evolving and maturing, optioneering and final decisions about design features are ongoing and expected to undergo further iteration as the design progresses.

1.4.2 Rolls-Royce SMR Ltd plan to prepare the initial BAT case for a generic RR SMR for Revision 2 of the E3S case, this will be aligned to design baseline at that time (currently Reference Design 7).

1.4.3 The optimisation methodology will be subject to a continuous review and improvement cycle. It will be reviewed and updated periodically to reflect feedback from users, lessons from other projects and any developments in environmental policy and legislation.

2 Overview of Regulatory Framework

2.1 Introduction

2.1.1 Rolls-Royce SMR approach to BAT methodology is the integration of BAT to achieve holistic optimisation of the RR SMR. However, BAT has a specific meaning and requirements in environmental legislation.

2.1.2 Section 2 presents an overview of the regulatory framework around the use of BAT to prevent, or where this is not possible, minimise the generation and disposals of radioactive wastes, and the consequent impact on people and the environment. Further details of relevant national and international legislation, as well as regulatory guidance and RGP can be found in the references provided.

2.1.3 A comprehensive definition of BAT is provided in the Regulatory Guidance Series No. RSR 2 [1] and the Radioactive Substances Regulations (RSR) Principles of Optimisation (v2) guidance [2] and has been reproduced below for context:

…the latest stage of development (state of the art) of processes, of facilities or of methods of operation which indicate the practical suitability of a particular measure for limiting discharges, emissions and waste. In determining whether a set of processes, facilities and methods of operation constitute the best available techniques in general or individual cases, special consideration shall be given to:

1. *Comparable processes, facilities or methods of operation which have recently been successfully tried out;*
2. *Technological advances and changes in scientific knowledge and understanding;*
3. *The economic feasibility of such techniques;*
4. *Time limits for installation in both new and existing plants;*
5. *The nature and volume of the discharges and emissions concerned.*

It therefore follows that what is "best available techniques" for a particular process will change with time in the light of technological advances, economic and social factors, as well as changes in scientific knowledge and understanding.

If the reduction of discharges and emissions resulting from the use of best available techniques does not lead to environmentally acceptable results, additional measures have to be applied.

"Techniques" include both the technology used and the way in which the installation is designed, built, maintained, operated and dismantled.

2.2 Environmental Permitting (England and Wales) Regulations 2016

2.2.1 Schedule 23 of the Environmental Permitting (England and Wales) Regulations 2016 (as amended) (EPR16) [3] provides the legal framework for regulating activities involving the use of radioactive substances, the generation of radioactive wastes and the disposals of those radioactive wastes into the environment. It adopts, in part, the Euratom Basic Safety Standards Directive (BSSD) laying down the requirements for protection against the dangers arising from exposure to ionising radiation [4] - and is consistent with the International Basic Safety Standards (BSS) published by the International Atomic Energy Agency (IAEA) [5].

2.2.2 The requirement to apply BAT to minimise the generation, disposal and impacts of radioactive wastes is set out in Schedule 23 of EPR16, which requires that:

In respect of a radioactive substances activity that relates to radioactive waste, the regulator must exercise its relevant functions to ensure that:

1. *All exposures to ionising radiation of any member of the public and of the population as a whole resulting from the disposal of radioactive waste are kept as low as reasonably achievable, taking into account economic and social factors, and*

2. *The sum of the doses resulting from the exposure of any member of the public to ionising radiation does not exceed the dose limits set out in Article 13 of the BSSD subject to the exclusions set out in Article 6(4) of that Directive.*

2.2.3 Environment regulators (Environment Agency, EA, and Natural Resources Wales, NRW) meet this obligation by requiring designers and operators of nuclear facilities to use BAT to minimise the generation of waste, its disposal to the environment and the consequent impact of such waste disposals on members of the public and the environment. These requirements are imposed through conditions attached to operational radioactive substances activities permits granted under EPR16 – particularly, permit conditions 2.3.1, 2.3.2 and 2.3.3, respectively reproduced below [6]:

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

2. *The operator shall use the best available techniques in respect of the disposal of radioactive waste pursuant to this permit to:*

    a. *Minimise the activity of gaseous and aqueous radioactive waste disposed of by discharge to the environment.*

    b. *Minimise the volume of radioactive waste disposed of by transfer to other premises.*

    c. *Dispose of radioactive waste at times, in a form, and in a manner so as to minimise the radiological effects on the environment and members of the public.*

3. *The operator shall use the best available techniques to:*

a. *Exclude all entrained solids, gases and non-aqueous liquids from radioactive aqueous waste prior to discharge to the environment.*

b. *Characterise, sort and segregate solid and non-aqueous liquid radioactive wastes, to facilitate their disposal by optimised disposal routes.*

c. *Remove suspended solids from radioactive waste oil prior to incineration.*

2.2.4 Other permit conditions with a bearing on optimisation and the use of BAT include 3.1.3 and 3.2.1 [6]:

1. *Subject to condition 3.1.1, the operator shall dispose of each form of solid and non-aqueous liquid radioactive waste by an optimised disposal route for that waste form.*

2. *The operator shall:*

   a. *Use the best available techniques when taking such samples and conducting such measurements, tests, surveys, analyses and calculations, and carrying out such environmental monitoring programmes and retrospective dose assessment, unless particular techniques are specified in schedule 3 of this permit or in writing by the Agency.*

2.2.5 It is noted that EPR16 also provides the mechanism for implementation of broader UK Government obligations, policy objectives and national strategies that have a bearing on the use of BAT to prevent or minimise the generation and disposal of radioactive waste, key among which are:

1. UK Strategy for Radioactive Discharges [7], which implements the requirement of the Oslo and Paris (OSPAR) Conventions on the application of BAT to minimise and, where appropriate, eliminate radioactive discharges from the nuclear industry into the marine environment of the North-East Atlantic.

2. UK Strategy for the Management of Solid Low-Level Radioactive Waste from the Nuclear Industry [8].

3. Policy for the Long-Term Management of Solid Low-Level Radioactive Waste in the United Kingdom [9].

4. The Joint Guidance on the management of higher activity radioactive waste on nuclear licenced sites [10]

2.2.6 The EA have published further guidance that contain provisions relating to the application of BAT, including:

1. The Regulation of Radioactive Substances Activities on Nuclear Licensed Sites, Regulatory Guidance Series, No. RSR 2 [1].

2. RSR: Principles of optimisation in the management and disposal of radioactive waste [2].

3. How to comply with your environment permit for radioactive substances on a nuclear licensed site [6].

2.2.7 In addition to the provisions relating to radioactive substances, EPR16 also makes provisions that deliver other legislative requirements arising from other international obligations and national policy objectives. One of such provisions that is pertinent to the RR SMR is the Industrial Emissions Directive (IED). The IED is implemented via different Schedules in EPR16:

1. Schedule 15, Large Combustion Plants, implements Chapter III of the IED.

2. Schedule 7, 'Part A installations' implements Chapter II of the IED.

2.2.8 The IED requires all 'installations' to apply BAT. BATC documents are the reference for relevant BAT and shall be reference for setting permit conditions. Permit conditions stricter than BAT may be set but only where this is necessary to ensure that no significant pollution is caused [11].

2.2.9 It is expected that BATCs [12] will be adopted for each of the sectors covered by a BREF. Until BATCs are available, relevant provisions from existing BREFs apply.

2.2.10 As stated in 1.3.2 there are several SSCs in the RR SMR conventional islands (T01, C01, B01) and CVI for which there are no established BAT positions, for such systems the methodology described in this document can be used to determine BAT.

2.3 Generic Design Assessment (GDA) Guidance for Requesting Parties

2.3.1 The EA has published guidance for Requesting Parties (RPs) regarding the GDA New Nuclear Power Plants (NPPs) [13]. The guidance provides an overview of the GDA process and identifies what information RPs are required to submit when requesting a GDA. The guidance refers to the development of an environment case by RPs, described as the collection of documents submitted to substantiate that the nuclear power plant design:

1. Meets regulatory requirements and expectations; and

2. Uses BAT to prevent or minimise harm to people and the environment.

2.3.2 Key information requirements and expectations relating to BAT during GDA are largely consistent with the permitting conditions outlined earlier and include:

1. Description of the optimisation process used to identify and justify the proposed techniques as BAT.

2. Demonstration that RPs' proposals represent BAT for monitoring.

3. Information about conventional aspects of the design, including information about the approach to applying BAT (where applicable).

2.4 RSR Objective and Principles

2.4.1 The EA recently published its RSR Objective and Principles (ROPs) [14]. The ROPs set out the fundamental objective of RSR regulation and the regulatory principles the Environment Agency applies in the delivery of its function as laid out in EPR16 and government policy. The ROPs replace the RSR Environmental Principles (REPs), which have hitherto guided regulatory decision making [15].

2.4.2 The ROPs are supported by a set of RSR Generic Developed Principles (GDPs) [16], which set out the Environment Agency's expectations on permit holders carrying out radioactive substances activities. A review of all the GDPs relevant to the RR SMR has been carried out as part of the ongoing generic regulatory design evaluation process. Details of the GDPs relevant to optimisation and the use of BAT are presented in Section 3.

2.5 Sustainability Framework

2.5.1 For decades, sustainable development has been an important component of UK government policy on the environment and has often been a material consideration in regulatory decision making. In recent years, several legislations have been enacted to provide firm legal basis for sustainability and the demonstration of the sustainability of development proposals is increasingly becoming a requirement of environmental regulation in England and Wales. The overall objective of these legislation is to achieve and leave a cleaner, greener and more resilient country for the next generation.

2.5.2 Some of the key legal instruments focusing on sustainability are highlighted below.

1. **Environment Act 1995**: This Act of parliament established the EA and provides that "it shall be the principal aim of the Agency…in discharging its functions to protect or enhance the environment, taken as a whole, as to make the contribution towards attaining the objective of achieving sustainable development…".

2. **Well-being of Future Generations (Wales) Act 2015** [17] - The Well-being of Future Generations (Wales) Act is about improving the social, economic, environmental and cultural well-being of Wales. It makes the public bodies listed in the Act think more about the long-term, work better with people, communities and each other, looking to prevent problems and take a more joined-up approach.

3. **The Environment (Wales) Act 2016** [18] - Part 1 sets out the sustainable management of natural resources' (SMNR), defined in the act as using natural resources in a way and at a rate that maintains and enhances the resilience of ecosystems and the benefits they provide. In doing so, meeting the needs of present generations of people without compromising the ability of future generations to meet their needs, and contributing to the achievement of the well-being goals in the Well-being of Future Generations Act. NRW must pursue SMNR in relation to Wales and NRW must apply the nine principles of SMNR into its ways of working to discharge its regulatory functions and duties. The principles of SMNR include adaptive management, collaboration and engagement and building resilience and will help NRW develop nature based and joined up solutions.

4. **Environment Bill 2020** - Sets out how UK Government plan to protect and improve the natural environment in the UK [19]. The Environment Bill helps to manage the impact of human activity on the environment, creating a more sustainable and resilient economy, and enhancing well-being and quality of life. It will engage and empower citizens, local government and businesses to deliver environmental outcomes and create a positive legacy for future generations.

The Environment Bill has been prepared through consultations with the public on numerous measures, including: environmental governance; the clean air strategy; biodiversity net gain; trees; conservation covenants; extended producer responsibility for packaging; recycling; a deposit return scheme for drinks containers and water.

Environmental principles will work together to protect the environment from damage by making environmental considerations central to the policy development process across government. The Bill legally obliges policymakers to have due regard to the environmental principles policy statement when choosing policy options, for example by considering the policies which cause the least environmental harm. The principles are:

a) Environmental protection should be integrated into policy-making principle;

b) The preventative action to avert environmental damage principle;

c) The precautionary principle;

d) Environmental damage should as a priority be rectified at source principle and;

e) The polluter pays principle.

5. **Environment Agency's EA2025 Plan** [20] - In 2020, the EA published a five-year plan, 'EA2025 creating a better place', to guide their activities and enable the realisation of the vision of a healthier, greener and more prosperous country in 2025 [14]. The EA2025 plan sets out three long-term goals:

   a. A nation resilient to climate change.

   b. Healthy air, land and water.

   c. Green growth and a sustainable future.

The goals, which are consistent with the United Nation's (UN) Sustainability Development Goals (SDGs), align with the regulation of nuclear sites as they help ensure that nuclear facilities are designed and operated in ways which minimise waste and protect the environment.

3 RR SMR: Underlying Environmental Principles

3.1 Introduction

3.1.1 A set of Environmental, Safety, Security and Safeguards (E3S) principles have been established for the design basis of the RR SMR. These are published in the Rolls-Royce SMR Environment, Safety, Security and Safeguards Design Principles, referred to as the E3S Principles document [21]. These principles present a distillation of established and endorsed international practices for plant and site design and provide a framework against which the design is evaluated and developed.

3.1.2 Section 3 focuses primarily on the fundamental environmental principles that support the design of the RR SMR. These principles have largely been drawn from UK regulatory requirements, guidance, and RGP.

3.1.3 An overview of other key related principles is also provided in this Section.

3.2 E3S Principles

3.2.1 The fundamental E3S objective is to protect people and the environment from harm. This requires the RR SMR to be designed such that it can be constructed, commissioned, operated, maintained, and decommissioned to control and reduce risks from both nuclear and conventional sources of potential harm.

3.2.2 The fundamental objective is achieved through hierarchical decomposition to a set of design principles that cover distinct thematic areas. The principles are translated into hard requirements that the design must achieve. Other design principles are not mandatory and are given as guidance that the design should strive to achieve, but failure to do so does not represent a foundational failure to achieve the fundamental objective or gross departure from established good practice or a failure of legal obligation. For each instance that a non-mandatory principle is not applied, a recorded justification that it is not reasonably practicable to do so is required. The principles cover all E3S areas and cover themes such as Internal Hazards, Defence in Depth, BAT and ALARP.

3.3 Applicable Environmental Principles

3.3.1 The key environmental principles underpinning the design of the RR SMR include:

1. <u>Optimisation and BAT</u>

    a. The design of the RR SMR will seek to prevent the generation of wastes, and where that is not practicable, to minimise the creation and disposal of such wastes to the environment and their attendant human and environmental impacts to ALARA. This will be accomplished through the application of BAT over the lifecycle of the reactor and associated systems. The concept of proportionality will be applied to the RR SMR design optimisation, with greater effort and resources allocated to aspects of the design where greater environmental benefits can be realised. Principles specifically related to the application of BAT have been adopted from the RSR: objective and principles [14] and the RSR GDPs: regulatory assessment [16].

b. BAT Principle No. 1: Use of BAT to minimise waste – the design of the RR SMR will use BAT to ensure that production of radioactive waste is prevented and where that is not practicable, minimised with regards to activity and quantity [Principle RSMDP3]. BAT is incorporated into engineering design process (Section 4) to ensure that due consideration is given to elimination of waste where possible, and where it can't be prevented, waste in all forms is minimised:

   i. Segregation of waste – The best available techniques should be used to prevent the mixing of radioactive substances with other materials, including other radioactive substances, where such mixing might compromise subsequent effective management or increase environmental impacts or risks.' [Principle RSMDP8].

   ii. Design for Decommissioning – The RR SMR will be designed and built using BAT to minimise the impacts on people and the environment that could arise during its decommissioning and the management of decommissioning wastes [Principle DEDP3].

c. BAT Principle No. 2: Methodology for Identifying BAT – BAT will be identified using a methodology that is timely, transparent, inclusive, based on good quality data, and properly documented [Principle RSMDP4]. RR SMR BAT methodology is incorporated into engineering design process and is based on RGP as described in this document (Section 4).

d. BAT Principle No. 3: Application of BAT – In determining BAT, the RR SMR design will seek to achieve a balance across safety, environmental, societal, and economic aspects. Any benefit or reduction in detriment that can be achieved, however small, will be secured so long as the associated cost is not grossly disproportionate to the benefits achieved [Principle RSMDP6]. The approach to demonstrating the application of BAT for RR SMR is structured upon the claims-arguments-evidence model, and the methodology for gathering and evaluating BAT options has been aligned with, and integrated, into the design decision process for the RR SMR to allow a holistic consideration and optimisation of all the key factors influencing design decisions (Section 4).

e. BAT Principle No. 4: BAT to Minimise Environmental Risk and Impact – The RR SMR design will apply BAT when making decisions about the management of radioactive (and other) substances, over the lifecycle of the facility, to ensure that the resulting environmental risk and impact are minimised [Principle RSMDP7]. Using BAT to minimise environmental risk and impact is equally applicable to conventional impacts:

   i. Resource consumption – The design of the RR SMR will seek to minimise the use of resources (e.g. water, energy and raw materials) wherever possible, provided this does not interfere with safety or operational considerations.

2. <u>Waste Hierarchy</u>

   a. The RR SMR design will adopt the waste management hierarchy in developing radioactive waste strategies and management plans. The waste hierarchy is fundamental to decision-making on the management of radioactive wastes. It is not directly applied as a strict, quantitative hierarchy as many complex factors influence the optimal management of any given waste or material. The hierarchy is captured in RR SMR Design Key Objectives and Assessment Criteria [22] (number 5), see Section 3.4 and used in options assessment (Section 4). The RR SMR will be designed with a 'concentrate and contain' philosophy for managing radioactive wastes, although it is recognised that the option to 'dilute and disperse' may be more appropriate in certain situations where it can be demonstrated to represent BAT.

b. More specifically, the waste hierarchy is further incorporated into decision-making through high-level BAT claims, covering radiological and conventional environmental aspects, established to support the demonstration of BAT in the design of the RR SMR. These Claims are described in Section 5.3.

3. Sustainable Development

   a. The Company vision is to provide clean affordable energy for all through the deployment of our RR SMR. The RR SMR can play a vital role in enabling the global transition to Net Zero. As a responsible, ethical, company we also need to make sure we operate as a sustainable business including our offices and future manufacturing sites. Sustainability is important to our regulators, our investors, our customers, and our employees.

   b. The RR SMR will be designed with the objective of addressing current energy resource and environmental/climate challenges, in a manner that would not compromise the ability of future generations to meet their own needs, and achieving optimum harmonisation between environmental, social and economic outcomes. Sustainability considerations have been integrated into the design optioneering process (Section 4).

   c. Rolls-Royce SMR Ltd are committed to going beyond the provision of low carbon nuclear electricity towards:

      i. Developing a long-standing sustainable business through alignment with the UN SDGs and other RGP, such as the Essentials Guide to Sustainable Management of Natural Resources and Well Being [23].

      ii. Embedding sustainability in decision making across all workstreams and at all levels of our organisation.

      iii. Establishing measures to baseline our sustainability credentials and ensure ongoing and continuous improvement.

      iv. Ensuring our sustainable approach is applied to future business.

   d. Modularisation – The RR SMR will be modularised to facilitate greater control of plant production processes, increase build certainty, maximise standardisation and to minimise the environmental impacts associated with fabrication, manufacture, build, commissioning, maintenance, and the decommissioning, dismantling and disposability of the plant and associated infrastructure. Modularisation is also a key engineering principle of RR SMR which supports sustainable development.

4. Precautionary Principle

   Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.

   At its heart, precaution represents a challenge to purely "evidence-based" risk-management practices. Instead, the precautionary principle points out that when full evidence is lacking, we should err on the side of caution and regulate potential threats, if those could cause serious or irreversible damage [24]. Recognising that RR SMR is FOAK, and there is limited OPEX (that is directly relevant) adequate and proportionate conservatism has been incorporated into the hazard, safety, environmental and other E3S analysis, supporting the design, to ensure design meets fundamental E3S objective to not cause harm to people or the environment.

5. Proximity Principle

   The principle of proximity implies that waste should generally be managed as near as possible to its place of production, mainly because transporting waste has a significant environmental impact. The principles of self-sufficiency and proximity (commonly referred to as the 'proximity principle') are set out in Article 16 of the Waste Framework Directive [25]. The proximity principle is used to help inform decision(s) on optimised disposal routes for waste. As such, it will mainly be considered during site specific permitting, however consideration will be given when considering both disposal routes and long-term storage options. Note: use of proximity principle does not require the absolute closest facility to the exclusion of all other considerations. There are clearly some wastes which are produced in small quantities for which it would be uneconomic to have a facility next to each area where waste generated. The ability to source waste from a range of locations and organisations helps ensure existing capacity is used effectively and efficiently.

3.3.2 Rolls-Royce SMR Ltd have reviewed all relevant GDPs, and other GDPs relevant to design of RR SMR include RSMDP8 (Segregation of wastes), RSMDP9 (Characterisation), RSMDP10 (Storage) and RSMDP13 (Monitoring and assessment).

3.3.3 The E3S principles (including environmental principles outlined above) are incorporated into the design process via requirements and the RR SMR design key objectives and assessment criteria to deliver the Rolls-Royce SMR vision of clean affordable energy for all.

3.4 Key Objectives and Assessment Criteria

3.4.1 The RR SMR key objectives and assessment criteria, explicitly incorporate criterion on environment, safety and security alongside technical feasibility, cost, and market factors [22]. These criteria are aligned with the UN SDGs and the goals of the Wellbeing of Future Generations (Wales) Act (WoFG) and have been incorporated into the RR SMR design process through the optioneering process and Decision Record Template. The 20 criteria are presented in

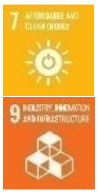
3.4.2

3.4.3 Table 1.

Table 1 Rolls-Royce SMR Key Objectives and Assessment Criteria

ID	Category	Key Objective	Metric	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.	Environment Safety, Security, Safeguarding (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?	E3S		Healthier
3	Safety	Support continuous safety improvement, meeting the Basic Safety Objective (BSO) 1e-6/yr but targeting 1e-7 CDF/yr	CDF/yr. Safety comparison, looking at impact on fault schedule /PSA and compatibility with safety targets.	E3S		Healthier

ID	Category	Key Objective	Metric	Sustainability Categories	UN SDG	WoFG
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.	E3S		Healthier
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.	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.	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)	Socio - Economic		Prosperous

ID	Category	Key Objective	Metric	Sustainability Categories	UN SDG	WoFG
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. (Compare through life cost impacts on O&M etc).	Economic, Environment, Social		Prosperous Globally Responsible
9	Cost	Minimise cost of decommissioning and associated impact(s)	£ (compare the impact on decommissioning complexity and costs).	Economic, Environment		Prosperous Globally responsible
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.	Socio-Economic, Environment		Prosperous
11	Program-me and Cost	Minimise build schedule duration	Compare manufacturing and build duration (yrs) (build target <3yrs).	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.	Socio-Economic		Prosperous Cohesive communities

ID	Category	Key Objective	Metric	Sustainability Categories	UN SDG	WoFG
13	Program-me and Cost	Maximise use of proven technology (minimise development cost/risk)	TRL/MCRL/MTRL assessment and development risk measured as a development cost (£) comparison, taking account of technology development and substantiation.	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.	Socio-Economic		Prosperous
15	Program-me	Development Programme Timescale {REDACTED FOR PUBLICATION}	Risk to achieving deployment date - a measure of development programme timescale.	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 and public purse).	Socio-Economic		Prosperous Cohesive communities

ID	Category	Key Objective	Metric	Sustainability Categories	UN SDG	WoFG
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.	Socio-Economic		Prosperous
18	Market	Capable of global expansion	Compatibility with global regulatory bodies and specific targeted regional requirements.	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.	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.	Socio-Economic		Prosperous

4 Overview of Rolls-Royce SMR Design Decision Process

4.1 Introduction

4.1.1 This Section gives an overview of Rolls-Royce SMR's Design Decision Process. It presents an outline of the Model Based Systems Engineering (MBSE) approach adopted by Rolls-Royce SMR and a summary of the design optioneering and decision-making process. The design optioneering and decision-making process effectively constitute the methodology for identifying and applying BAT in the design of the RR SMR.

4.2 Rolls-Royce SMR's Engineering Design Approach

Model Based Systems Engineering

4.2.1 Rolls-Royce SMR Ltd. has adopted a requirements-led approach based on the MBSE framework for the RR SMR Power Station Development Programme. The MBSE is defined as the formalised application of modelling to support system requirements, design, analysis, verification and validation activities beginning in the conceptual design phase and continuing throughout development and later life cycle phases [26].

4.2.2 The MBSE framework is used to establish a clear definition of the design requirements for all SSCs comprising the power station, and to manage such requirements from conception through to the generation and development of design concepts that fulfil those requirements. 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.

Definition and Management of Requirements

4.2.3 The design process begins with the definition of requirements, arising from identification of a problem or opportunity, or from existing stakeholder requirements (e.g. allocation from design level above). It involves identification and engagement with a range of stakeholders with legitimate interest in the matter at hand, and clearly defining the scope and boundaries of the problem or opportunity. Stakeholder needs covering the entire project lifecycle – including relevant assumptions – are elicited, written into appropriately structured sets of requirements and validated.

4.2.4 The aim of this exercise is to define, develop, document and release a set of clear and consistent requirements that address the needs of all stakeholders. It seeks to ensure that all lifecycle stages are considered and that an agreed set of requirements is available against which a design solution can be developed and verified. Requirement definition is not necessarily linear and is inherently iterative, and so this process is revisited many times throughout design.

4.2.5 The following Section provides an overview of the Rolls-Royce SMR's structured design decision process.

4.3 Design Optioneering Process

4.3.1 Generation of design concepts and identification of the preferred design solution to fulfil defined requirements is achieved through a structured design optioneering process, illustrated in Figure 1 below.

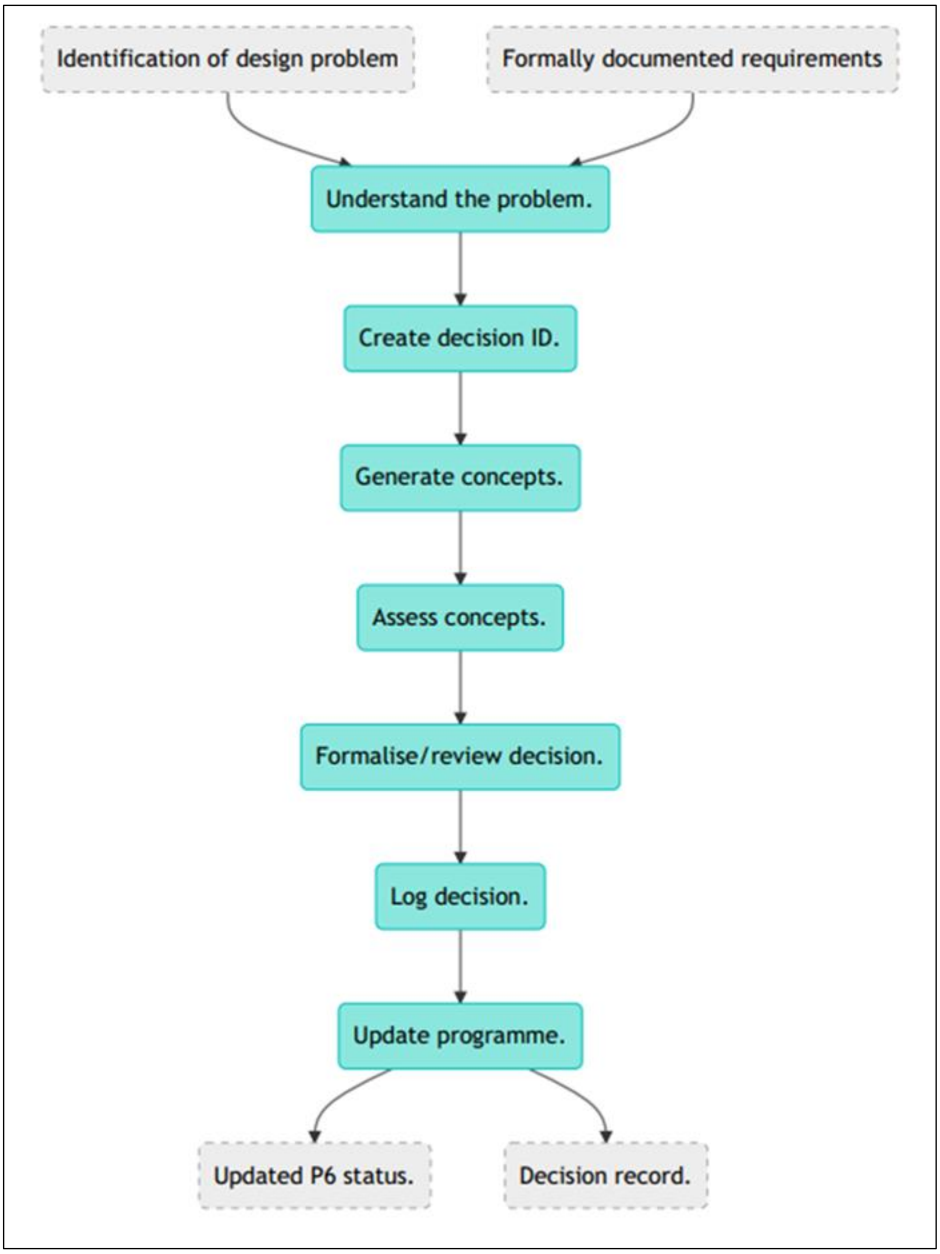


Figure 1 Conduct Design Optioneering Process

4.3.2 The optioneering process ensures that:

1. The scope and boundaries of the problem/opportunity/requirement triggering the design activity are well understood.
2. Relevant stakeholders are identified and involved.
3. RGP and OPEX are identified and considered.

4. There is traceability in the decision-making process.

5. Decisions are formally approved and recorded.

4.3.3 An overview of each of the design optioneering steps shown in Figure 1 is presented below. Details of decisions taken at each Step of the optioneering process, along with supporting information, justifications and underpinning evidence, are captured in the Design Decision Record TS-DD-02.

4.4 Step 1: Understand the problem

Define the Scope of the Decision

4.4.1 This Step of the optioneering process involves consideration of the requirement, problem, or opportunity to be addressed by the design exercise, and identification and engagement with relevant stakeholders such as designers of interfacing SSCs, E3S team, cost engineers. External stakeholders such as system vendors or other competent persons may also be engaged at this step where appropriate.

4.4.2 This is followed by a clear definition of the scope and boundaries of the design decision such that it is consistently understood by all stakeholders. Any inputs required to support to the decision-making process (e.g. technical reports, analyses, calculations and description of interfacing SSCs) are clearly identified at this stage. Similarly, related decisions or milestones that either feed into the decision or are impacted by the outcome of this decision are identified and recorded.

4.4.3 The level of governance to be applied is decided by assigning a Decision Level, whilst the decision analysis method to be used is determined following an Impact and Complexity scoring exercise.

Assign Decision Level

4.4.4 Design decision making follows a hierarchical structure, with each decision allocated to one of six decision levels, which then defines the appropriate level of governance for the decision. The Chief Engineer (CE) holds ultimate responsibility for assigning decision levels (but may delegate this responsibility). Table 2 presents the five decision levels and the persons responsible for decisions made at each level.

4.4.5 Decision Level 0, which refers to major business decisions to be taken at a strategic level by board members. The Executive Leadership Team (ELT) are responsible for such decisions. These are beyond the scope of this document and have therefore not been included in Table 2.

Table 2 Decision Levels

Decision Level	Description	Responsibility for Decision
1	A major design decision to be taken within the senior management of the project.	CE
2	A major power station integration level design decision to be taken at the CE's first line. An incorrect decision could adversely impact on the regulatory case, on overall cost or time to market.	CE's First Line
3	A key decision to be taken within the senior management of the design area. Typically, at 'island' level (e.g. T01). Could impact on the safety, security or environmental case. They will have minimal impact across the broader power station.	Chief Design Engineer
4	A key design decision to be taken in one of the design teams. Have an impact at the system level and could have an impact on the safety, security or environmental case.	Design Manager
5	Design optimisation/progression. Has a minimal impact on the safety, security or environmental case. Incorrect decisions have minimal impact on the plant design, and no impact on the safety, security or environmental justification or plant performance.	Design Engineer

4.4.6 For all decision levels, an assessment of options is undertaken to identify the preferred option and a subsequent decision record must be completed in a proportionate manner to provide transparency as to why a decision was taken. For Levels 1 to 4 decisions, the assessment of options must consider BAT, ALARP and Secure-by-Design and the decision record must accurately reflect the outcome of the assessment. E3S Teams are engaged in the decision-making process for decisions at these levels. For Level 5 decisions, it may be disproportionate to undertake a detailed decision analysis and a rationalised approach may be justified. Where specifying that a decision is at Level 5, this should be discussed and agreed with the E3S Team to ensure that no unrecognised E3S impact have been missed.

Assign Complexity and Impact Score

4.4.7 Complexity and impact scorings are carried out to aid the selection of decision analysis method. Impacts are evaluated against a set of pre-defined E3S and project criteria, and scored as either High, Low or Medium, with the rationale for the assigned score recorded.

4.4.8 Impact of decisions on E3S criteria are evaluated on an unmitigated basis, assuming that the decision is executed wrongly. For example, decisions that could result in exceedance of Basic Safety Levels (BSL) if wrongly executed are assigned a high score, whilst a low score is assigned to decisions whose wrong execution would result in an impact that is below the BSO. A medium score signifies a decision which would result in impacts between the BSL and BSO if wrongly executed.

4.4.9 The criteria against which E3S impacts are scored and guidelines on how to assign scores are presented in Table 3 below.

Table 3 E3S Impacts and Complexity Scoring

Criteria	Guidelines for Assigning Scores
Safety levels and Safety objectives	{REDACTED FOR PUBLICATION}
Safety classification	{REDACTED FOR PUBLICATION}
Conventional safety	{REDACTED FOR PUBLICATION}
Environmental Controls	{REDACTED FOR PUBLICATION}
Security and safeguards controls	{REDACTED FOR PUBLICATION}

4.4.10 The overall impact of a decision on E3S is determined based on the maximum score across all five E3S criteria.

4.4.11 In addition to the E3S criteria, the impact of the decision on the project elements (cost, programme, and performance), should the wrong decision be made, and its complexity (e.g. number of dependencies and interfaces), are evaluated. The guidelines for project impacts and complexity scoring are illustrated in Table 4 below.

Table 4 Project Impacts and Complexity Scoring

Criteria	Guidelines for Assigning Scores
Cost	{REDACTED FOR PUBLICATION}
Programme	{REDACTED FOR PUBLICATION}
Performance	{REDACTED FOR PUBLICATION}
Complexity - number of SSCs involved	{REDACTED FOR PUBLICATION}
Complexity - stakeholder involvement	{REDACTED FOR PUBLICATION}

4.4.12 As with the E3S scoring, impact of a decision on the project and its complexity is determined based on the maximum score across all project and complexity criteria.

Select decision analysis method

4.4.13 The outcome of the E3S impacts and project impacts & complexity scoring exercise is then used to inform the selection of the most appropriate options evaluation (optioneering) method. Three qualitative and semi-quantitative optioneering methods have been established to support the decision analysis:

1. For Low impact decisions, a simple comparison of the advantages and disadvantages of different options is considered sufficient.

2. For Medium impact decisions, a Red-Amber-Green (RAG) assessment is deemed sufficient.

3. For High impact decisions, a semi-quantitative assessment using the Pugh Matrix is required.

4.4.14 The decision analysis method selected must be agreed with the design manager and E3S team, with a note added to the Decision Record to confirm that this has been done, and who approved it.

4.5 Step 2: Create Decision ID

4.5.1 This administrative Step involves the generation and assignment of an identification (ID) number for the decision and logging the decision in the Decision Register maintained in IBM Dynamic Object Orientated Requirement System (DOORS). This Step is executed by the systems Integration Engineer, following a request for Decision ID from a Design Engineer.

4.6 Step 3: Generate Design Concepts

4.6.1 This Step identifies feasible design concepts for consideration using the Functional Means Analysis (FMA) approach. FMA is a structured approach for generating, screening and documenting design concepts used to identify the means for achieving specified functions and the associated requirements (i.e. functional and non-functional performance requirements). It begins with the generation of a wide range of diverse options, followed by an appraisal of the feasibility of individual concepts and combinations thereof.

4.6.2 Design concepts/options for assessment are typically gather using various means including:

1. Reviews of RGP and OPEX data, including for example relevant codes and standards and design solutions proposed for other new build facilities or implemented in operating facilities[1].

2. Options elicitation exercises, involving subject matter experts, as well as relevant internal and external stakeholders where appropriate.

3. Engagement with system vendors and operators of other facilities.

4.6.3 The output from this step is a set of viable options/design concepts to taken forward for further evaluation at the concept assessment step. A concise description of the key attributes of each option/design concept to be taken forward (including any differentiating features) is prepared to aid the understanding of the concept by relevant stakeholder ahead of options assessment step.

4.6.4 Selected design concepts must provide a solution that reduces risks to ALARP, applies BAT and features Secure-by-Design.

4.6.5 All concepts that are considered shall be captured in the Decision Record TS-DD-02. Where they are not considered to be feasible, this shall be recorded with associated rationale, before removing them from the list of options that is taken forwards.

4.7 Step 4: Assess Design Concepts

4.7.1 A preferred option is identified from the feasible concepts shortlisted in the previous step using a structured evaluation process. The design evaluation (optioneering) step is performed using one or more of the three qualitative and semi-quantitative approaches listed in Paragraph 4.4.13. The use of qualitative and semi-quantitative approaches facilitates proportionate evaluation of design concepts in a manner that is commensurate with the impact/complexity of the design decision at hand.

4.7.2 It is possible that in some cases, several options remain in contention after the FMA step. In such instances, a coarse screening step may be employed to streamline the number of options carried forward for further analysis. The objective of the coarse screening step is to eliminate options that are clearly sub-optimal, enabling a more efficient evaluation of preferred options at the main assessment step. It is recommended that fewer than five options are shortlisted and carried forward to the main assessment step.

4.7.3 A summary of the three options assessment methods is presented below.

[1] The European IPPC Bureau have published BAT Reference and BAT Conclusions documents, containing BAT recommendations for number of industrial processes [12]. Design engineers of conventional RR SMR plants and systems should check the Bureau website to see if published BAT positions can deliver defined requirements.

Advantages vs Disadvantages:

4.7.4 This assessment method is suited to decisions with low impact/complexity scores. As the name implies, it involves a simple comparison of the advantages and disadvantages of a set of design concepts in order to identify the preferred option. This method can also be used for coarse screening of potential options for design decisions with a medium or high impact/complexity score.

Red, Amber, Green (RAG):

4.7.5 This assessment method is suited to decisions with a medium impact/ complexity score. It involves evaluation of shortlisted design concepts against a set of nine evaluation criteria, namely:

1. Technical (meets performance spec).
2. Cost & Business Case.
3. Programme Timescale.
4. Build Certainty.
5. Security Compliance.
6. Nuclear Safety/ALARP.
7. Conventional Health and Safety.
8. Environment/BAT.
9. Social, Economic, Other.

4.7.6 For each design concept, a score of Red (Bad), Amber (Acceptable) or Green (Good) is assigned for each criterion, and the rational for the score assigned recorded. The scores for each option are then tallied and the preferred option identified. The RAG method may also be used for coarse screening of potential options for design decisions with a high impact/complexity score.

Pugh Matrix:

4.7.7 This options evaluation method is suited to decisions with a high impact/complexity score. The Pugh Matrix is a semi-quantitative decision analysis technique that applies numerical scores against a set of evaluation criteria to discriminate between options. The assessment may be performed by a responsible engineer in consultation with the E3S team, or through a workshop involving relevant stakeholders and Suitably Qualified and Experienced Person (SQEP) resources – depending on the significance of decision in question. The key elements of the Pugh Matrix assessment include:

1. A baseline option is identified (often based on the existing design concept) and assigned a neutral score (zero) across all evaluation criteria.

2. The shortlisted design options are then evaluated and assigned a score ranging from -2 to +2 (relative to the baseline option) against each evaluation criteria, with rationale/evidence for the scoring recorded.

3. Weighting factors are then applied to each criterion and the overall scores are calculated to inform the preferred option. The weighting factors are pre-defined by the CE and must not be changed. It is noted that the scoring is carried out before applying weighting factors to avoid bias – which could happen when the total scores are visible.

4. Sensitivity analysis may be performed (e.g., by altering the weighting assigned to a criterion) where appropriate – for example, in situations where options have very similar total scores or where some evaluation criteria have a disproportionate influence on the decision.

5. The outcome of the Pugh Matrix assessment is then recorded, and the preferred option identified.

Evaluation criteria used to in the Pugh Matrix approach are consistent with 20 the key design objectives outlined in

4.7.8 Table 1. Weighting factors have been pre-assigned to each evaluation criterion to reflect their relative significance to the project.

4.7.9 Pugh Matrix Assessment is used to guide decision making and encourage holistic evaluation of options against the key criteria. While the option that scores the highest may well be selected for inclusion within the design, this is not mandated and an option that scores well against the safety criteria but poorly against the cost and programme may still be selected if deemed appropriate. Such considerations form part of the subsequent technical review where the outcome of the Pugh Matrix assessment is reviewed, and a preferred option selected for endorsement.

Environment Optioneering Matrix

4.7.10 An Environmental Optioneering Matrix (EOM) tool and associated guidance [27] have been produced to support design engineers carrying out a more detailed evaluation of the potential impacts of design concepts on the environment. There are a significant number of different aspects or attributes that are represented under the criteria ‘environmental’ including (but not limited to) radioactive and conventional solid, liquid, and aerial waste streams, resource and raw material usage, noise, odour, indirect impacts, and compliance with legislation. Not all attributes or aspects will be applicable to the options or decision being considered. Consideration needs to be given up front to which are the important attributes for the options under consideration.

4.7.11 The EOM has been developed to assist engineering design leads with:

1. Deciding and capturing which environment attributes/aspects should be considered under Criterion 5 for each decision/option/problem under consideration.

2. Capturing the detailed environmental benefits and disadvantages of each option.

3. Scoring each environmental attribute for each option relative to each other.

4. Recording the justification of each score.

4.7.12 The completed EOM can be used as a precursor to the RAG or Pugh matrix to help identify from an environmental perspective which options should be ruled out due to their environmental impact and identifies those options that are or would be acceptable from an environmental standpoint. It can also be used as supporting evidence to help justify the scoring of the environment criterion (RAG/Pugh matrix) and to demonstrate that consideration has been given to a wide range of environmental attributes.

4.7.13 Further information on the EOM and associated guidance can be found in Reference [27].

Consideration of BAT References and Conclusions

4.7.14 It is recognised that formalised BAT positions have been recommended and endorsed by the European Commission and UK authorities [12] for some conventional plants and systems. Such recommendations have been published in BAT Reference and BAT Conclusion documents, which are publicly available.

4.7.15 In situations where BAT recommendations for conventional systems have been published (e.g., identified in Step 3), such recommendations should be considered for adoption as preferred design concept and Step 4 of the optioneering process abbreviated. Where alternative design concepts are considered more appropriate to the context of the RR SMR, suitable justification should be provided. In either case, supporting information and evidence need to be documented in the Decision Record.

4.8 Step 5: Formalise/Review Decision

4.8.1 This step brings together all the information gathered in the preceding steps in a structured and coherent manner in the Decision Record to aid decision making. It presents a concise account of the design optioneering process – including information on the preferred option, alternative options considered, the decision-making method used, the evaluations made during decision making, the criteria considered, and who approved the decision. The reasoning (including any supporting evidence) behind all optioneering decisions is recorded to aid traceability across the design process.

4.8.2 Sufficient level of detail that can support the demonstration that the preferred option fulfils both E3S and project requirements is provided. Some of the information presented include:

1. An overview of the preferred option (highlighting key architectural and design aspects of the option) and those rejected (with the rationale for rejection), including a summary of any sensitivity analysis carried out to support the optioneering process.

2. Brief statements justifying that the selected option presents a solution that reduces risks ALARP, applies BAT, features Secure-by-Design and is Sustainable. This highlights the key discriminating factors that has informed the selection of the recommended option from an E3S and project perspectives.

3. A short account of any additional analysis, design work or further decisions required to mature the chosen concept, including recommendations for further work.

4.8.3 All the above information is captured and formally recorded in the Decision Record. Decision Records are assigned a document number, signed off by authorised persons and issued via the document control. A summary of the decision approval process is presented in Section 4.10.

4.9 Steps 6/7: Log Decision and Update Programme

4.9.1 This is another administrative Step involving an update of decisions in the Decisions Register. The Systems Integration Engineer makes an entry into the Decisions Register, capturing a summary of the outcome of completed Design Decisions.

4.9.2 A summary of the outcome of each decision is recorded in a design Decision Register. The Decision Register is structured against the Product Breakdown Structure and acts as a master list of all decisions planned and taken on the programme, such that they can be readily reviewed/referenced. It represents a key body of evidence that underpins regulatory processes such as the GDA or site permitting. It is managed/maintained in IBM DOORS and is subject to formalised change control with baselines being taken at the end of each design phase, as a minimum.

4.9.3 The status of the decision is then updated in the project plan by the Project Manager.

Configuration and Change Management

4.9.4 The design of RR SMR will become subject to Configuration and Change Management (CCM) from the DRP onward. CCM ensures the engineering product design and supporting configuration are baselined and change managed throughout the lifecycle stages of the programme. (i.e. design, substantiation, realisation, commissioning, entry into service and operation of the power station).

4.10 Decision Making

4.10.1 Responsibility for decision making is determined by the assigned decision level, described in Section 4.2. In arriving at a decision, the decision maker reviews the information presented in the Decision Record and related evidence and considers broader project objectives and constraints to reach a conclusion about the preferred option recommended by the design engineer. The decision maker may approve or reject the recommendation, or raise further actions where appropriate.

4.10.2 For high impact or high complexity decisions, recommendations from the design engineer may be deliberated by a decision panel comprising competent stakeholders from relevant disciplines, who may challenge or endorse the recommendation to the decision maker for approval. The outcome of such deliberations is recorded in memos or minutes of meetings.

4.11 Facilitating the Design Process

4.11.1 The E3S team play a key role in facilitating/supporting the design process, with the overall aim of ensuring that decisions on proposed design solutions are robust and underpinned by appropriate evidence, capable of supporting the E3S case. Some of the ways in which the E3S team contribute to the design process are summarised below.

Engineering/Design Support

4.11.2 The E3S team is a key stakeholder in the RR SMR engineering design process and support the development of design concepts from the very beginning. Examples of the contribution of the team to the engineering design process include:

1. Definition of E3S requirements that must be considered by design engineers alongside the functional requirements specific to their SSCs.

2. Review of early design concepts and design proposals and engaging with design engineers to ensure the implementation of E3S principles.

3. Participation in optioneering workshops, Hazard and Operability (HAZOP) studies and other design review meetings (including decision panel sessions) to scrutinise proposed design concepts.

Capacity building

4.11.3 Further, the E3S team is involved with capacity building through the delivery of training to design engineers on the implementation of BAT, ALARP and Secure-by-Design to ensure holistic optimisation of the design and raise the competency of engineers. A two-tier training programme targeting different levels of interest in design optimisation has been conceived and is in development:

1. General awareness – This training is open to anyone with an interest in design development, introducing the fundamental principles of BAT, ALARP and Secure-by-Design, and the associated regulatory and good practice bases for these principles.

2. Practitioner – This training will be mandatory for design engineers or other roles with product design responsibility, describes how the above principles are implemented over the lifecycle of a product/SSC and how this can be used to satisfy project objectives and demonstrate compliance with regulatory requirements.

4.12 Summary of Decision Process

4.12.1 Key elements of the design optioneering process described in the above Section has been adapted into a simplified, more descriptive summary of the decision process for use as part of the RR SMR design optimisation training package. The adapted summary is presented in Figure 2 and Table 5 below and is reproduced here for completion.

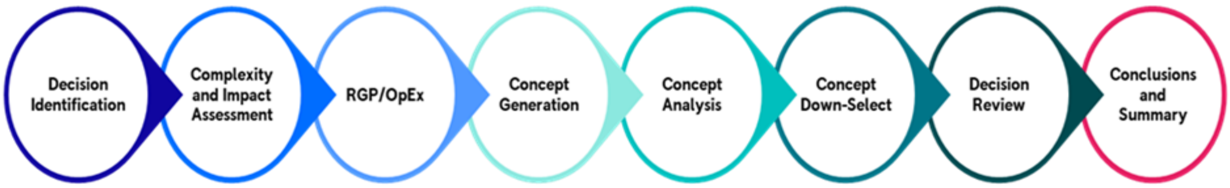


Figure 2 Rolls-Royce SMR Simplified Design Decision Process

4.12.2 Brief descriptions of the steps in the simplified decision process are provided in Table 5 below. These have been aligned to the steps in the formal/ detailed decision process presented in the preceding Sections for context. Some administrative steps (e.g. Steps 2, 6 and 7) described in the formal decision process have not been explicitly included in the simplified process and therefore omitted from Table 5.

Table 5 Summary of Rolls-Royce SMR Simplified Design Decision Process

Formal process step	**Simplified process step**	**Description**
Step 1: Understand the problem	Decision Identification	Decision context description, decision level (who's responsible for signing-off), defines the function(s) that this design optioneering fulfils and the purpose of the SSCs that deliver the function.
	Complexity & impact assessment	Determines optioneering/depth of analysis required, high level assessment against RR SMR key assessment & objectives.
Step 2: Create Decision ID	Not applicable	Administrative.
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	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 take forward for detailed assessment in the next step.
	Concept analysis	Provide detailed description of the design concepts/options identified in the previous step.
Step 4: Assess concepts	Concept down-selection	Coarse screening (if required) to reduce identified concepts to <5 viable options for detailed valuation.
	Decision Review	Detailed Evaluation of Options: Strengths and limitations for each option are evaluated in turn for different attributes (including safety, security, environmental protection, cost, schedule, and programme). Identifies the key points that may be used to discriminate between the options.
Step 5: Formalise/Review Decision	Conclusions and Summary	Decision analyses and conclusion – evidence – supported selection of the BAT (ALARP/Secure-by-Design) Option.
Step 6/7 Log Decision and Update Programme	Not applicable	Administrative step.

5 Demonstrating the Application of BAT for RR SMR

5.1 Introduction

5.1.1 The BAT assessment is fully integrated into the Rolls-Royce SMR design process. As stated at the start of Section 4 the design optioneering and decision-making process effectively constitutes the methodology for identifying and applying BAT in the design of the RR SMR.

5.1.2 Section 4 gave an overview of the design decision process, including the integrated approach used to identify and select a preferred design concept that fulfils a defined requirement. The evidence justifying why a preferred design concept/option represents a solution that reduces risks ALARP, applies BAT, features Secure-by-Design and is Sustainable forms a key input into the design decision process for the RR SMR. This evidence and associated information (including any supporting OPEX, analyses, calculations, studies, etc.), documented in the Decision Record, provides the basis for demonstrating the use of BAT in the design of the RR SMR, and for developing the BAT case.

5.1.3 The following Sections describe how the information recorded in the Decision Records is presented in a logical and structured manner as the overall RR SMR BAT Case.

5.2 BAT Case Structure for RR SMR

5.2.1 The demonstration of BAT for the RR SMR will follow the Claims Arguments Evidence (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. This model is well-established in the UK and is routinely used in the development of safety cases for nuclear facilities.

5.2.2 In broad terms,

1. Claim: An assertion of truth or statement. 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 is met, covering E3S Principles.

2. Sub-Claim: Logical decomposition of a Claim.

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

4. Evidence: Justification and underpinning of the Claims and Sub-Claims. 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.

5.2.3 Use of the CAE approach to demonstrate BAT has been successfully applied in previous NPP submissions and is considered by the EA to provide a suitable basis for the identification of BAT [28]. High level claims on the application of BAT in the design of the RR SMR, have been derived from UK regulatory precepts and established RGP [14] [16] [6]. These claims are outlined in Sub-section 5.3.

5.2.4 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.

5.3 Fundamental BAT Claims

5.3.1 A set of seven high-level claims, covering radiological and conventional environmental aspects, have been established upfront to support the demonstration of BAT for the RR SMR. These Claims have primarily been based on RR SMR key assessment and objectives (see Section 3), requirements set out in EPR16 (particularly Schedules 7, 8 and 23) and associated regulatory guidance [6] and RGP, for example References [14] and [16]. The claims also incorporate sustainability objectives based on sustainable development principles (see Section 3), with emphasis on the environment protection aspects. It is noted that the socio-economic and governance aspects of sustainable development are addressed in the wider Rolls-Royce SMR sustainability policy [29].

5.3.2 The seven fundamental BAT Claims, comprising five radiological and three conventional (non-radiological) claims, are listed below.

5.3.3 Radiological BAT Claims:

1. Claim 1: The RR SMR eliminates or reduces the generation of radioactive waste.
2. Claim 2: The RR SMR minimises the amount of radioactivity discharged or disposed of to the environment.
    a. Subclaim 2a: The leakage of primary and secondary coolant is minimised.
    b. Subclaim 2b: The discharge of gaseous radioactive wastes to the environment is minimised.
    c. Subclaim 2c: The discharge of aqueous radioactive wastes to the environment is minimised.
    d. Subclaim 2d: Activity of other radioactive wastes is minimised.
3. Claim 3: The RR SMR minimises the volume of radioactive waste disposed of too other premises.
4. Claim 4: The RR SMR minimise the impacts on the environment and members of the public.
    a. Subclaim 4a: Radioactive waste discharges routes and structures are optimised.

b. Subclaim 4b: Final disposal routes for other wastes and spent fuel are optimised.

5.3.4 Conventional (non-Radiological) BAT Claims:

1. Claim 1: The RR SMR minimises the use of resources (water, energy, materials and space/footprint).

2. Claim 2: The RR SMR minimises the emission of substances which could give rise to environmental impact (e.g. chemicals, hydrocarbons, greenhouse gases, ozone depleting substances, etc.).

3. Claim 3: The RR SMR minimises the conventional environmental impact of the design:

    a. Subclaim 4a: Sustainable materials selection.

    b. Subclaim 4a: Substitution of materials with less hazardous alternatives.

    c. Subclaim 4a: Noise, odours and other nuisance are optimised.

5.3.5 The above claims are applicable to all the lifecycle phases of the RR SMR (from the current design stage to the decommission stage), 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.

5.4 Production of the RR SMR BAT Case

5.4.1 The RR SMR BAT case is prepared by a small 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.

5.4.2 In parallel, a systematic review of SSCs included in the GDA boundary document [30] (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 these SSCs are then gathered and the BAT justifications recorded are used as evidence to substantiate the arguments presented for each claim are pulled out and used to populate the BAT framework. To enhance the design optimisation process, the BAT case team will engage with design engineers and the design integration engineers, where appropriate, to clarify the basis of design decisions and seek further evidence where the information presented in the Decision Records are inadequate.

5.4.3 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.

5.4.4 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 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.

6 Summary and Conclusions

6.1 Summary

6.1.1 The fundamental objective for the RR SMR is 'to protect people and environment from harm', can be achieved at all lifecycle stages of the power station. The realisation of this fundamental objective is demonstrated by means of the E3S case.

6.1.2 The E3S case must demonstrate that the design of the RR SMR applies the principles of ALARP, BAT and Secure-by-Design and incorporates RGP to provide confidence that the RR SMR is fully optimised with no fundamental showstoppers within the design that would impact on safety, environment, or security.

6.1.3 The approach to demonstrating the application of BAT is structured upon the CAE model. The methodology for gathering and evaluating BAT options is aligned with, and integrated, into the design decision process for the RR SMR to allow a holistic consideration and optimisation of all the key factors influencing design decisions.

6.1.4 The Appendix to this document provides an outline of the four fundamental radiological claims and the supporting arguments. One of the arguments and the underpinning evidence substantiating Claim 2 is also presented to demonstrate how the CAE structure is being implemented.

6.1.5 The BAT methodology has been updated significantly to reflect how it has matured alongside the design optioneering process. A summary of changes and improvements are:

The RR SMR key design principles and assessment criteria

6.1.6 A number of the RR SMR key objectives and assessment criteria have been strengthened and they are now aligned with the UN SDGs and the goals of the Wellbeing of Future Generations (Wales) Act. The criteria are incorporated into the design optioneering process for the RR SMR through the Decision Record Template.

Decision Record temple

6.1.7 The Decision Record template underwent a major update in October 2022:

1. The document was restructured to improve the flow, and a number of sections including the Environment section were strengthened with additional guidance to support the engineers.
2. Sustainability was added as a sub-section in the environment section, with guidance on how sustainability can be considered in other criterion and sections.
3. Requirement to complete a BAT and Sustainability summary added into the Conclusions section of the template.

Environmental Optioneering Matrix Template and Guidance

6.1.8 EOM has been developed by the E3S team to assist Engineering with scoring and justifying each option for environmental aspects that are important for a particular decision. The completed template can then support and provide additional evidence for the scoring under 'environment' criteria in the associated completed decision records.

Training

6.1.9 Mandatory BAT and optimisation training course for engineers have been developed. The training also incorporates key sustainability principles and EOM. Training is face to face and includes interactive session. The existing BAT and Optimisation training course is being extended to include ALARP and Secure-by-Design.

6.2 Forward actions

6.2.1 BAT is an iterative process and as such the methodology will require modification and update as the design process matures, options are agreed, RGP is updated, and optimisation of the chosen option(s) becomes the focus of the design phase.

6.2.2 The following Forward Actions (FA) are proposed to ensure methodology is reviewed in a timely manner:

6.2.3 FA1: Regular review methodology and update as necessary as the engineering design matures (minimum for start of Step 3).

6.2.4 FA2: 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 (by end Step 2).

6.2.5 FA3: Review Environmental Protection Function Categorisation methodology to ensure consistency with the BAT methodology.

7 Appendix A: BAT Case Example

7.1 Introduction

7.1.1 The RR SMR BAT case is structured around/built upon the four fundamental radiological BAT claims and related subclaims identified in Section 5. This Appendix provides an outline of these four claims and the supporting arguments. One of the arguments and the underpinning evidence substantiating Claim 2 is presented to demonstrate how the CAE structure is implemented.

7.2 RR SMR BAT Case Structure: Summary of Claims and Arguments

7.2.1 The body of evidence substantiating the RR SMR BAT claims and subclaims is currently being gathered alongside the maturing design; however, an indicative set of arguments justifying each of the BAT Claims have been formulated, based on the RR SMR design features and RGP. The preliminary claims, subclaims and indicative arguments framework for the RR SMR BAT case (based on the Preliminary Concept Design) are presented in Table 6 below.

Table 6 Preliminary RR SMR Claims, Subclaims and Arguments

Claim 1: The Design of RR SMR Eliminates or Reduces the Generation of Radioactive Waste
Summary of Claim 1 Arguments and Evidence
Fuel Design, Manufacture & Management Supporting arguments are likely to cover the following topics: C1-A1: Design of RR SMR Fuel C1-A2: The Fuel Manufacturing Process C1-A3: Fuel Handling
Fuel Efficiency Supporting arguments are likely to cover the following topics: C1-A4: Design of RR SMR Reactor Core C1-A5: Optimisation of Fuel Enrichment, Fuel Burn-up and Fuel Cycle
Detection and Management of Failed Fuel Supporting arguments are likely to cover the following topics: C1-A6: Monitoring and Detection Techniques for Failed Fuel C1-A7: Procedures for the Management of Failed Fuel
Control of Materials Corrosion and Activation Supporting arguments are likely to cover the following topics: C1-A8: Specification of Reactor & Primary Circuit Materials C1-A9: Management of Reactor Coolant Chemistry C1-A10: Commissioning, Start-up and Shutdown Procedures
Control of Tritium in the Primary Coolant Supporting arguments are likely to cover the following topics: C1-A11: Boron-free Operation
Control of Other Gas Generation in the Primary Coolant C1-A12: Specification of Secondary Neutron Sources

Claim 2. The Design of RR SMR Minimises the Amount of Radioactivity Discharged or Disposed to the Environment
Summary of Claim 2 Arguments and Evidence
Subclaim 2a: The leakage of primary and secondary coolant is minimised
Primary Circuit Containment and Leak Minimization Supporting arguments are likely to cover the following topics: C2-A1: RR SMR Primary Circuit Containment C2-A2: Prevention/Minimisation of Leaks from the Primary Circuit C2-A3: Containment Leak Monitoring and Collection C2-A4: Containment Venting and Filtering
Secondary Circuit Chemistry Optimisation and Leak Detection Supporting arguments are likely to cover the following topics: C2-A5: Optimisation of Secondary Coolant System Chemistry C2-A6: Monitoring for Steam Generator Leaks
Subclaim 2b: The discharge of gaseous radioactive wastes to the environment is minimised
Discharge of Gaseous Radioactive Wastes to the Environment Supporting arguments are likely to cover the following topics: C2-A16: Decay of Short-lived Volatile Fission Products C2-A17: Filtration of Gaseous Discharges C2-A18: Minimisation of the Transfer of Radioactivity to the Secondary/ Turbine Coolant Circuit C2-A19: Consideration of Techniques for Reducing the Discharge of Gaseous Tritium and Carbon-14
Subclaim 2c: The discharge of aqueous radioactive wastes to the environment is minimised
Management of Liquid Effluents Supporting arguments are likely to cover the following topics: C2-A7: Effluent Segregation C2-A8: Treatment of the Segregated Waste Streams
Coolant & Liquid Effluent Treatment Supporting arguments are likely to cover the following topics: C2-A9: Removal of Activation Products from Solution with Ion Exchange C2-A10: Selection of Ion Exchange Resins C2-A11: Filtration of Liquid Discharges C2-A12: Decay Storage of Liquid Effluent Prior to Discharge C2-A13: Techniques to Reduce Liquid Tritium Discharges
Evaporation of Liquid Discharges Supporting arguments are likely to cover the following topics: C2-A14: Evaporation of Coolant for Recycling in the Primary Circuit C2-A15: Evaporation of Non-recycled Effluents from the Primary Circuit
Subclaim 2d: Activity of other radioactive wastes is minimised
Management of Spent Fuel and ILW Supporting arguments are likely to cover the following topics: C2-A20: Spent Fuel Pool C2-A21: Control of Pool Water Temperature and Chemistry C2-A22: Containment of ILW
4.10 Decay Storage of Solid Radioactive Waste Supporting arguments are likely to cover the following topics: C2-A23: Decay of Cobalt-60, Caesium-137 and Iron-55

C2-A24: Decay of Dry Active Waste and Spent Water Filters
Claim 3. The Design of RR SMR Minimises the Volume of Radioactive Waste Disposed of to Other Premises
Summary of Claim 3 Arguments and Evidence
Minimising Volumes of Operational and Decommissioning Wastes Supporting arguments are likely to cover the following topics: C3-A1: Rooms, Systems and the Materials/Design for Decommissioning C3-A2: Shielding and Barriers C3-A3: Design for Ease of Maintenance/Decommissioning C3-A4: Minimisation of Filter Usage & Disposal
Application of Volume Reduction Processes to Solid Wastes Supporting arguments are likely to cover the following topics: C3-A5: Design of the Waste Management Facilities C3-A6: Compaction (High Force and Low Force) C3-A7: Use of Diversified Waste Routes C3-A8: Incineration and Thermal Treatment
Claim 4. The Design of RR SMR Minimises the Impacts on the Environment and Members of the Public
Summary of Claim 4 Arguments and Evidence
Subclaim 4a: Radioactive waste discharges routes and structures are optimised
Preferential Partitioning of Radionuclides Supporting arguments are likely to cover the following radionuclides: C4-A1: Tritium C4-A2: Iodine isotopes C4-A3: Carbon-14
Liquid Effluent Discharges Supporting arguments are likely to cover the following topics: C4-A4: Maximising Dilution and Dispersion in the Marine Environment
Gaseous Waste Discharge Structures Supporting arguments are likely to cover the following topics: C4-A5: Height of Main Discharge Stack
Subclaim 4b: Final disposal routes for other wastes and spent fuel are optimised
Radioactive waste management and storage facilities Supporting arguments are likely to cover the following topics: C4-A6: Adequate provisions have been incorporated in the design to allow future management of predicted arisings of radioactive wastes by operators
Solid and non-aqueous liquid LLW Supporting arguments are likely to cover the following topics: C4-A7: All predicted arisings of solid and non-aqueous liquid LLW have established disposal routes in the UK
HAW and Spent Fuel Supporting arguments are likely to cover the following topics: C4-A8: Disposability Case demonstrate that all predicted Solid HAW and Spent Fuel arisings are compatible with NWS Disposal Concepts and the UK's Proposed GDF

7.2.2 Development of the CAE framework for the RR SMR BAT Case is ongoing and the partial framework presented above will continue to be progressed and refined in an iterative manner as the design of relevant RR SMR SSCs matures. The claims subclaims and arguments presented in Table 6 are therefore likely to change.

7.2.3 An illustration of how the application of BAT is demonstrated within the RR SMR BAT Case using the full CAE framework is provided in Section 7.4. The illustration focuses on subclaim 2b: the design of the RR SMR minimises the discharge of gaseous radioactive waste to the environment, and provides the evidence that substantiate one of the key arguments used to justify subclaim 2b.

7.3 Subclaim 2b: the RR SMR minimises the discharge of gaseous radioactive wastes to the environment

7.3.1 Gaseous radioactive wastes primarily arise from the degassing of vessels and tanks containing radioactive liquids (primary coolant, etc.), evaporative losses from the spent fuel pool and associated pools, and leakages from process systems and pipework into building atmospheres. Gaseous radioactive wastes thus generated are collected and abated prior to discharge to the environment by two key systems - the Gaseous Waste Treatment System (GWTS) [KPL] and the Reactor Island Heating, Ventilation and Air Conditioning (HVAC) system [KL].

7.3.2 SSCs in the RR SMR are aligned to the Standard Reference Designation System for Power Plants (RDS-PP). [KPL] and [KL] are the RDS-PP designation for the GWTS [KPL] and the Reactor Island HVAC system [KL].

7.3.3 Another source of gaseous radioactive waste is the turbine condenser, which forms part of the secondary coolant circuit in the T01. The secondary coolant is not normally radioactive; radioactive contamination arises from the transfer of radioactive effluent from the primary (reactor) coolant circuit via small primary-to-secondary leaks within Steam Generator (SG) tubes. The leaked effluent is transported across the secondary circuit to the turbine condenser where the solubilised fraction is retained, and non-condensable gases (including radioactive gases) stripped by the Condensed Air Removal System (CARS) [MAJ] and discharged to the environment via a stack.

7.3.4 Subclaim 2b indicates the potential arguments and evidence likely to be presented to demonstrate that the design of the RR SMR minimises the discharge of gaseous radioactive wastes, in support of higher-level Claim 2. The CAE structure for subclaim 2b are illustrated in Table 7.

Table 7 Proposed CAE Framework of RR SMR BAT Subclaim 2b

Claim 2: The RR SMR minimises the amount of radioactivity discharged or disposed of to the environment
Subclaim 2b: The RR SMR minimises the discharge of gaseous radioactive wastes to the environment
Argument 1: Decay of short-lived volatile fission products
Overview of GWTS [KPL]
Evidence 1: Selection of techniques for abating short-lived volatile fission products
Evidence 2: Sizing and design optimisation of charcoal delay beds
Evidence 3: Design of the nitrogen cover gas network

Evidence 4: Transfer of moisture from the gas stream to drains
Evidence 5: In-process sampling and monitoring of the KPL system
Argument 2: Filtration of gaseous radioactive waste discharges
Overview of HVAC system
Evidence 1: HVAC system configuration
Evidence 2: HVAC design to maintain negative pressure
Evidence 3: Abatement of radioactivity by HEPA filters and iodine absorbers
Evidence 4: Demonstration of performance of HEPA filters and iodine absorbers Adsorbers
Evidence 5: Removal of moisture and solubilised radioactivity
Argument 3: Minimised Transfer of Radioactivity to the Secondary (Turbine) Coolant Circuit
Overview of secondary/ turbine coolant circuit
Evidence 1: Design, manufacture, and management of SG tubes
Evidence 2: Primary-secondary leak detection/monitoring
Evidence 3: Turbine condenser design
Evidence 4: Filtration of CARS [MAJ] exhaust
Argument 4: Consideration of Techniques for Reducing the Discharge of Gaseous Tritium and Carbon-14
Evidence 1: Consideration of RGP and OPEX on tritium removal techniques
Evidence 2: Consideration of RGP and OPEX on carbon-14 removal techniques
Evidence 3: RR SMR design features for reducing the generation and discharge of tritium and carbon-14

7.3.5 It is noted that the design of the HVAC system [KL] and CARS [MAJ] are in the early stages of development and there is insufficient information at this juncture to substantiate the arguments relating to these systems. The arguments and evidence provided to substantiate Subclaim 2b have therefore been centred around the key design features of the GWTS [KPL] and how these have been optimised to minimise the discharge of gaseous radioactive wastes to the environment. Future iterations of this document will include the arguments and evidence regarding the design and optimisation of HVAC system [KL] and CARS [MAJ].

Argument 1: Decay of short-lived volatile fission products

7.3.6 The design of the RR SMR incorporates a GWTS [KPL] for abating the discharge of volatile fission products (primarily short-lived radioisotopes of xenon and krypton, and iodine vapours) to the environment. An overview of this system is provided below.

<u>Overview of GWTS [KPL]</u>

7.3.7 The primary function of the GWTS [KPL] is to process gaseous effluent from the primary circuit containing hydrogen and volatile fission products, to prevent the formation of explosive atmospheres and reduce the radioactivity of gaseous effluent discharged to the environment. The key sources of these gases during power operation are the vacuum degasser in the processing & treatment system for liquid radioactive effluent (KNF) and Reactor Coolant Drain Tank (RCDT) in the collection & drainage system (KTA). KNF degassing operations (during reactor shutdown phase or following design basis fuel failure) are expected to generate significant quantities of hydrogen and fission product effluent. Similarly, the RCDT in KTA is a significant source of gaseous effluent as it receives reactor coolant during operation, including the pressuriser steam bleeds.

7.3.8 The KPL uses nitrogen cover gas to purge interfacing systems handling reactor coolant, primary circuit effluent or make-up water. The cover gas also minimises the ingress of air to prevent formation of flammable atmospheres and prevent aeration of primary circuit water. Cover gas is delivered by compressors and distributed via a combination of pressure and flow control.

7.3.9 Hydrogen and volatile fission products in vessel/tank headers are purged by the cover gas and collected as gaseous effluent. The hydrogen and oxygen content in the gas stream are constantly measured through analysers and are abated via the recombiner. The gas is cooled and dried to minimise moisture content, ensuring the performance of the recombiner and the charcoal delay beds. This cooling and drying step enables the separation of tritiated liquid effluent (and any entrained particulates) that has carried over into the gaseous phase.

7.3.10 Most of the nitrogen cover gas is recycled in a semi-closed loop. Excess gas during volume surges such as tank filling operations is directed to the delay beds where the volatile fission products are adsorbed by the activated charcoal and undergo decay prior to discharge to the environment (via the stack with HVAC providing the minimum air flow for a gaseous discharge).

7.3.11 The baseline architecture for the KPL system consists of:

1. A cover gas network distributing nitrogen to various interfacing systems handling primary circuit water (effluent or make-up).

2. A catalytic recombiner for H_2 and O_2 abatement.

3. Gas analysers and gas injection supplies constantly controlling the H_2 and O_2 content.

4. Gas compressors with liquid seal systems.

5. Control valves for controlling pressure and distributing the gaseous effluent flow.

6. A series of delay beds with an exhaust to the stack via the HVAC system. A dryer package and guard bed upstream protect the delay beds from excessive moisture that affect their performance.

7.3.12 A block flow diagram highlighting the key processes is shown below in Figure 3.

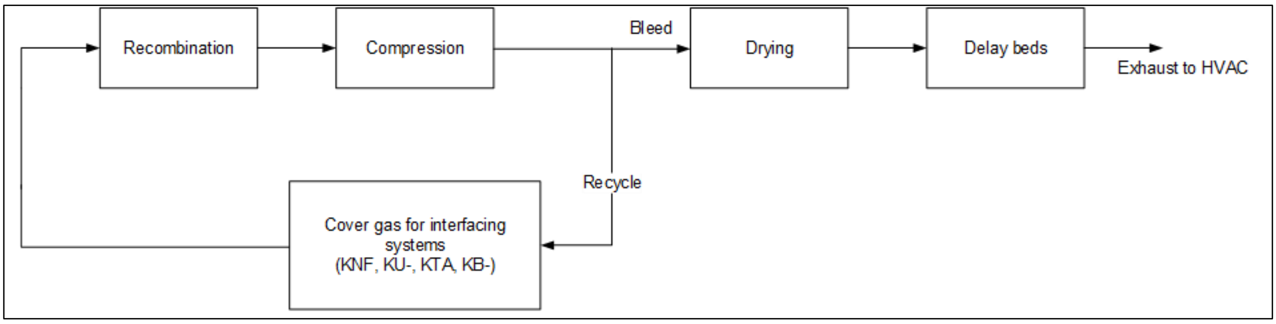


Figure 3 Block flow diagram for KPL

7.3.13 The following Section presents evidence demonstrating how the design of the GWTS has been optimised to minimise the discharge of gaseous radioactive wastes to the environment.

Evidence 1: Selection of techniques for abating short-lived volatile fission products

7.3.14 Decay storage of radioactive gases works through either confinement in a container or physical retention on a sorbent media, prior to discharge to atmosphere. The resulting delay in their release provides time for natural radioactive decay to reduce the activity of the gaseous wastes, thereby reducing the discharge of radioactivity to the environment. For example, over a period of time equivalent for four half-lives, natural decay will reduce the activity of a radioactive gas by nearly 94%. The technique is relevant to those gases that are difficult to abate because they are not chemically active and which have a short half-life. Decay storage does not exclude radioisotopes from eventual discharge, but is useful in reducing the release of activity in cases where there is no other viable treatment option.

7.3.15 For the RR SMR, two techniques for the hold-up and abatement of short-lived volatile fission products (primarily xenon and krypton, and iodine vapours) were considered in the design of the GWTS [KPL]. These are:

1. Use of activated carbon for dynamic adsorption of noble gases, delaying their flow for them to decay prior to release (option D0), and;

2. Use of pressurised tanks for storage and decay prior to release (option D1).

7.3.16 Both these techniques are generally well established and have advantages/disadvantages regarding BAT, ALARP and operational requirements.

7.3.17 A third option based on the use of cryogenic systems for separation of fission-product gases at extremely low temperatures was considered. This technique would enable abatement of the longer-lived fission products such as krypton-85 species, which is not practicable with the two techniques identified earlier. However, this option was ruled out from further consideration for the following reasons:

1. Cryogenic system is considered to result in very high operating costs due to the very low boiling point of krypton, and

2. There is little information on the process and limited examples of the deployment of this technique on other nuclear power plants and the availability of such technology is assumed to be low.

7.3.18 Summaries of the key features of option D0 and option D1, as well a brief account of the analysis undertaken, and the preferred option identified are presented below.

<u>Activated charcoal delay beds (baseline option D0)</u>

7.3.19 Activated charcoal delay beds are a known and widely used technology which are in operation at other nuclear power stations (both Boiling Water Reactors, BWRs, and PWRs). The charcoal in the delay beds works by adsorbing the gas as it passes through the beds, the time that the gas spends in the charcoal beds being based on the rate at which the gas adsorbs into the charcoal. The design and performance of the system can be optimised through temperature and pressure control, and flow measurement (higher pressures and lower temperatures result in better adsorption efficiency, whilst lower flow rates require less adsorbent).

7.3.20 This technique does not produce significant additional secondary wastes and the charcoal beds can be designed to last for the operating lifetime of the RR SMR. Secondary waste arisings associated with this system can thus be considered to be inherently minimised.

7.3.21 Delay beds are designed for the treatment of xenon and krypton isotopes (except for krypton-85 on account of its long half-life), but they also have a delay-decay effect on iodine isotopes that may be present in the gaseous waste. The German safety standard KTA 3605 [31] specifies krypton and xenon retention times for gaseous waste; the recommended times are 40 hours or more for isotopes of krypton and 40 days or more for isotopes of xenon. Recent PWR designs such as EPR and HPR 1000 reference the German safety standard in their design. These delay times have been determined to achieve reduction in the activity of these radioisotopes by a factor of 4370 [32]. Further increase in the delay time has been shown to have no significant benefit in reducing the level of radioactivity. For example, increasing the retention time by 50% would only further reduce the radioactivity of krypton-88 by 0.02% and that of xenon-133 by 0.47% [33]. Whilst this would provide limited benefit in terms of dose reduction, it would require disproportionate volume of activated charcoal that would ultimately become waste. A decay time of 40 hours and 40 days for krypton and xenon respectively is thus considered an optimal time to hold-up these noble gases.

Pressurised decay storage tank (alternative option D1)

7.3.22 This technique involves the compression of radioactive gases into decay storage tanks where they are retained for sufficient time to ensure that radionuclides with short half-lives have decayed to the required level prior to discharge. Greater allowable pressure of the tanks allows for greater storage capacity. The storage system can be configured to contain multiple decay tanks to provide operational flexibility – for instance to cope with the additional quantities of volatile fission-products degassed from primary coolant during shutdown operations.

7.3.23 The technique has the advantage that no secondary waste is generated. It is widely used in nuclear power plants and is a mature technology for the treatment of noble gases in PWRs [34].

Evaluation of options D0 and D1

7.3.24 A simple, qualitative comparative analysis of charcoal delay beds and decay storage tanks was carried out. The outcome of the analysis is summarised below:

1. Decay storage tanks are designed to be filled and emptied in batches and can therefore provide a longer decay time and the abatement of longer-lived gases such as Kr-85). The stored gas can be recycled and need only be released to stack upon high accumulation of gases following degassing operations or fuel failure, or as a result of volume surges during normal operations.

2. Decay storage tanks require no protection against moisture or chemical contaminant carry-over, nor do they require temperature control by the HVAC system.

3. With decay storage tanks there is flexibility for switching the order of tanks that receive the waste gas flow. This enables activity to be redistributed.

4. Decay storage tanks have higher capacity and space requirements than do charcoal delay beds designed for the same duty.

5. The storage tank system has more components (for the purpose of actuation and control) which will require more frequent maintenance with the associated risk of dose to operators.

6. Tank sampling requirements lead to potential dose to operators during normal operation.

7. Decay storage tanks have the conventional safety risk associated with pressurised storage tanks.

7.3.25 A semi-quantitative decision analysis against the RR SMR key design objectives/ criteria was also performed using the Pugh Matrix, with the baseline activated charcoal delay beds (option D0) assigned a zero score against all the decision criteria. The activated charcoal delay beds came out with a higher overall score and were deemed to have greater advantages over the alternative decay storage tanks.

<u>Preferred option</u>

7.3.26 Activated charcoal delay beds were considered more advantageous and ultimately selected in preference to the decay storage tanks for the following principal reasons:

1. Smaller space requirements.

2. Simplicity of operation, with the process only requiring moisture removal and pressure control.

3. More passive design that does not require much operator action or sampling.

4. Lower risk of erroneous discharge.

7.3.27 The activated charcoal delay beds technique for processing noble gases was deemed to be the optimal option for the RR SMR, reduces risks to ALARP and represents BAT.

7.3.28 Further optimisation of the RR SMR charcoal delay bed system was considered. This involves the incorporation of a 'guard bed' to protect the charcoal delay beds from contamination and moisture carryover, which degrades their performance. It is also noted that the first bed in the delay bed series will accumulate the majority of the activity in most operations and therefore present the highest operator dose risk (noting that some of the fission-product gases are gamma emitters). The use of a guard bed will confine some of the radioactivity (mostly halogens) to a smaller volume ($0.3m^3$), which can be physically separated from other delay beds, easing maintenance (and therefore reducing operator dose risk).

<u>Evidence 2: Sizing and design optimisation of charcoal delay beds</u>

7.3.29 Following the selection of activated charcoal delay beds as the preferred technique for abating short-lived volatile fission products, an initial evaluation of the design parameters required to achieve the desired performance requirements for the delay beds under different operating conditions (temperature, pressure/flow rate and relative humidity) was carried out. The delay beds are required to achieve hold-up times of 40hrs and 960hrs for krypton and xenon (respectively) [31]. The delay line also needs to be capable of processing the maximum anticipated surge volume of 200m^3 [35].

Mass of activated charcoal

7.3.30 Initial calculations of the mass of activated charcoal required to achieve the performance requirements for the delay beds outlined earlier have been carried out. The mass of charcoal can be found from the following equation from [36]:

$$M = \frac{V}{K_a}$$

Where:

M = Mass of charcoal (g).

V = Maximum surge volume (cm^3).

Ka = Adsorption coefficient of charcoal (cm^3/g).

7.3.31 The adsorption coefficient (Ka) represents the capacity of charcoal to hold-up noble gas prior to release and varies depending on the noble gas, with krypton having a much lower adsorption coefficient than xenon (roughly 6%). Thus, the krypton adsorption coefficient is used to give the most conservative mass of charcoal.

7.3.32 Adsorption coefficients are influenced by the characteristics of activated charcoal and operating conditions such as air pressure, Relative Humidity (RH), and temperature. Calculations were performed for multiple steady state operating conditions were performed using adsorption coefficients taken from supplier documentation [36].

7.3.33 Selected outputs from the calculations for specified steady state operating conditions are summarised in Table 8 below:

Table 8 Mass of Charcoal required for different operating conditions

Temperature (°C)	Pressure (Bara)	RH (%)	Ka (Kr)	Ka (Xe)	Charcoal mass for Kr (kg)
5	5	5	70	no data	590
5	1	5	98	2020	2108
21	5	5	45.4	no data	963
21	1	5	63.5	1100	3440

7.3.34 As evident from Table 8, the mass of charcoal required to achieve the desired hold-up time is a function of the pressure, RH and temperature. For a given temperature and humidity, over three and a half times more carbon (by mass) is required at 1 bara pressure, compared to that needed at 5 bara pressure. Operating conditions corresponding of 5°C temperature, 5% RH and 5 bara pressure would allow around 1000kg of activated carbon per delay bed and were considered optimum for the KPL system [35]. The size of the delay beds will be confirmed with suppliers in due course [37]. The potential risk of egress of gases from the delay line due to the greater than atmospheric pressure conditions is mitigated by the availability of HVAC system, which prevents build-up of any leaked gases.

7.3.35 Two delay beds arranged in series, each with volumes of approximately $3m^3$, would be required to provide the desired hold-up times:

1. One delay bed to have sufficient hold-up during normal operation. This allows one bed to be bypassed for maintenance and inspection during operation.

2. The two delay beds to have sufficient hold-up for design basis (e.g. following reactor coolant degassing after fuel failure).

7.3.36 A guard bed of activated charcoal ($0.3m^3$ volume) will be emplaced upstream of the two delay beds as contingency to act as a sacrificial bed to protect the delay beds from contaminants. The guard bed and first delay bed are expected to accumulate most of the activity and are recommended to be physically separated to minimise operator dose [37].

Evidence 3: Design of the nitrogen cover gas network

7.3.37 The nitrogen cover gas network uses compressors to provide inert nitrogen cover gas flow for purging/blanketing of systems handling primary coolant. This nitrogen gas purges atmospheres of vessels and pipework containing waste gases, maintaining low concentrations of volatile radionuclides, hydrogen and oxygen, as well as reducing the amount of oxygen in the primary circuit water to lower the amount of radioactive species produced in the core [38].

Choice of nitrogen as cover gas

7.3.38 RR SMR uses nitrogen gas to purge vessels and pipework containing waste gases. The choice of nitrogen as cover gas is based on evolution of the design of PWRs (which previously used hydrogen as cover gas). The switch to nitrogen reduces the conventional risks associated with the storage of large volumes of hydrogen on site. No formal options assessment has been carried out and its inclusion in the RR SMR design is based on benchmarking against world practice in PWR design and operations, and consideration of conventional safety issues. The use of nitrogen as a cover gas is deemed to be the BAT for the RR SMR for the flushing of components in the primary circuit [33].

7.3.39 The use of nitrogen as cover gas may result in a small increase in the generation of carbon-14 due to neutron activation of small quantities of the cover gas that dissolve in the primary coolant during processing. However, it is noted that the nitrogen cover gas prevents the aeration of, and subsequent dissolution of oxygen in, the primary coolant during processing, which could also lead to the generation carbon-14 due to neutron activation in the reactor core. It is therefore considered that the generation of carbon-14 due to dissolution of nitrogen in the coolant is effectively countered by the prevention of carbon-14 formation due to activation of oxygen arising from coolant aeration.

Semi-closed loop design

7.3.40 The cover gas network is configured to recycle the nitrogen cover gas during power operations in a semi-closed loop to minimise consumption of the gas. The cover gas and entrained volatile radioactivity is only directed/channelled/transferred to the delay beds.

7.3.41 This recycling configuration allows the hold-up (in a semi-continuous loop) and decay of short-lived radioactive gases purged from vessels containing primary coolant during power operations, prior to discharge to the environment. This preserves the life of the charcoal delay beds which are largely called into action only when excess gas is generated, for example in the lead-up to refuelling shutdown when the degassing of primary coolant results in excess waste gases.

7.3.42 It is recognised that the recycling configuration has the effect of accumulating longer lived radioactive gases such as Kr-85 (half-life of 10.7y) within the gas circuit. However, the contribution of this radionuclide to typical dose due to gaseous discharge from nuclear power stations is not significant [38].

Evidence 4: Transfer of moisture from the gas stream to drains

7.3.43 Moisture will be removed from the gaseous stream in several stages of the KPL, including:

1. The inlet and outlet of the recombiner, where moisture is removed by condensation through cooling with heat exchangers to required temperatures (10-20°C).

2. Compression of the circulating covers gas for reuse and separation of the resulting liquid effluent (and any entrained particulates).

7.3.44 Whilst the purpose of the moisture removal steps is to improve process performance rather than to expressly abate radioactivity from the gas stream, it has the effect of removing tritiated water vapour and any solubilised radioactivity from the gas stream, partitioning tritium and condensable radionuclides from the gas to the liquid phase, preventing their discharge to the environment.

Evidence 5: In-process sampling and monitoring of the KPL system

7.3.45 Effective operation/performance of the KPL system is influenced by the atmospheric conditions of the influent gas, which is defined by parameters including as temperature, pressure, flow rate, moisture levels, concentrations of hydrogen and oxygen.

7.3.46 To support the optimum performance, safe operation and control, the KPL system design incorporates several in-process sampling and/or monitoring instrumentation before and after key subsystems such as the recombiner and delay beds, to monitor a range of key systems parameters identified earlier, as well as the radioactivity levels. The monitoring system transmits information on these parameters to the operator in the control room and, during emergencies, the emergency control centre. These in-process monitoring steps will ensure the continued efficacy of the KPL in abating the discharge of gaseous radioactivity to the environment.

8 References

[1] Environment Agency, “The regulation of radioactive substances activities on nuclear licensed sites, Regulatory Guidance Series, No RSR 2, Version 2,” Environment Agency, 2012.

[2] Environment Agency, “RSR: Principles of Optimisation in the Management and Disposal of Radioactive Waste, Version 2,” Environment Agency, 2010.

[3] HMSO, “UK Parliment "The Environmental Permitting (England and Wales) Regulations",” December 2016. [Online]. Available: https://www.legislation.gov.uk/uksi/2016/1154/contents. . [Accessed January 2023].

[4] HMSO, “European Commission, “Council Directive 2013/59/Euratom”,” December 2013. [Online]. Available: https://www.legislation.gov.uk/eudr/2013/59/contents. [Accessed January 2023].

[5] International Atomic Energy Agency, “Radiation protection and safety of radiation sources : international basic safety standards, Vienna,” 2014. [Online].

[6] Environment Agency, “Guidance - RSR permits for nuclear licensed sites: how to comply,” 2022 February. [Online]. Available: https://www.gov.uk/government/publications/rsr-permits-for-nuclear-licensed-sites-how-to-comply/rsr-permits-for-nuclear-licensed-si. [Accessed 27 February 2023].

[7] Department of Energy and Climate Change, “UK Strategy for Radioactive Discharges,” 2009. [Online]. Available: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/249884/uk_strategy_for_radioactive_discharges.pdf. [Accessed 27 March 2020].

[8] Department of Energy and Climate Change, “UK Strategy for the Management of Solid Low Level Waste from the Nuclear Industry,” 2016. [Online]. Available: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/497114. [Accessed 24 March 2020].

[9] Defra, DTI and Devolved Administrations, “3. Policy for the Long-Term Management of Solid Low-Level Radioactive Waste in the United Kingdom,” 2007. [Online]. Available: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/254393/Low_level_waste_policy.pdf. [Accessed 24 March 2020].

[10] ONR, EA, NRW, SEPA, “Joint Guidance on the management of higher activity radioactive waste on nuclear licensed sites, Revison 2.1,” July 2021. [Online]. Available: https://www.onr.org.uk/wastemanage/waste-management-joint-guidance.pdf. [Accessed 23 3 2023].

[11] DEFRA, “Industrial emissions Directive EPR Guidance on Part A Installations,” 2013. [Online]. Available: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/221044/pb13898-epr-guidance-part-a-130222.pdf. [Accessed February 20].

[12] European Commission, “BAT reference documents,” European IPPC Bureau, [Online]. Available: https://eippcb.jrc.ec.europa.eu/reference/. [Accessed 01 March 2023].

[13] Environment Agency, “Guidance, New nuclear power plants: Generic Design Assessment guidance for Requesting Parties,” 29 October 2019. [Online]. Available: https://www.gov.uk/government/publications/new-nuclear-power-plants-generic-design-assessment-guidance-for-requesting-parties. [Accessed December 2022].

[14] Environment Agency, “Guidance: Radioactive substances regulation (RSR): objective and principles,” December 2021. [Online]. Available:

https://www.gov.uk/government/publications/radioactive-substances-regulation-rsr-objective-and-principles.. [Accessed February 2022].

[15] Environment Agency, “Regulatory Guidance Series RSR 1: Radioactive Substances Regulation – Environmental Principles (Version 2),” April 2010. [Online]. Available: https://www.gov.uk/government/publications/radioactive-substances-regulation-environmental-principles. [Accessed April 2021].

[16] Environment Agency, “RSR generic developed principles: regulatory assessment,” 1 December 2021. [Online]. Available: https://www.gov.uk/government/publications/rsr-generic-developed-principles-regulatory-assessment. [Accessed November 2022].

[17] National Assembly for Wales, “Deddf Llesiant Cenedlaethau’r Dyfodol (Cymru) 2015 / Well-being of Future Generations (Wales) 2015,” 2015. [Online]. Available: https://www.legislation.gov.uk/anaw/2015/2/contents/enacted/english. [Accessed 01 March 2023].

[18] Natural Resources Wales, “Introducing Sustainable Management of Natural Resources,” [Online]. Available: https://wcva.cymru/influencing/legislation/the-environment-wales-act/#:~:text=The%20Environment%20%28Wales%29%20Act%20puts%20in%20place%20the,commitment%20to%20introduce%20new%20legislation%20for%20the%20environment.. [Accessed January 2023].

[19] DEFRA, “30 January 2020: Environment Bill 2020 policy statement. (Updated),” 1 April 2022. [Online]. Available: https://www.gov.uk/government/publications/environment-bill-2020/30-january-2020-environment-bill-2020-policy-statement. [Accessed January 2023].

[20] Environment Agency, “Corporate report, Environment Agency: EA2025 creating a better place,” 9 Jul,y 2020. [Online]. Available: https://www.gov.uk/government/publications/environment-agency-ea2025-creating-a-better-place. [Accessed 13 February 2023].

[21] Rolls-Royce SMR, SMR0001603/001, “Rolls-Royce SMR Environment, Safety, Security and Safeguards Design Principles,” August 2022.

[22] Rolls-Royce SMR, SMR0003036/001, “Small Modular Reactor Programme Key Objectives and Assessment Criteria,” October 2022.

[23] Llywodraeth Cymru Welsh Government, “Essentials Guide to Sustainable Management of Natural Resources and our Well Being,” 2018. [Online]. Available: https://www.gov.wales/sites/default/files/publications/2019-06/sustainable-management-of-natural-resources-guide.pdf. [Accessed 24 February 2023].

[24] EUR-Lex, “Communication from the Commission on The precautionary principle,” 30 November 2016. [Online]. Available: https://eur-lex.europa.eu/legal-content/EN/LSU/?uri=CELEX:52000DC0001. [Accessed February 2023].

[25] European Commission, “Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives,” 19 November 2008. [Online]. Available: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32008L0098. [Accessed February 2023].

[26] International Council on Systems Engineering, “Systems Engineering Vision 2020 - INCOSE-TP-2004-004-02, Version 2.3,” September 2007. [Online]. Available: https://sdincose.org/wp-content/uploads/2011/12/SEVision2020_20071003_v2_03.pdf.

[27] Rolls-Royce SMR, SMR0002176/001, “RR SMR Environmental Optioneering Matrix and Guidance,” February 2023.

[28] Environment Agency, “Environment Agency and Natural Resources Wales, “Assessing new nuclear power station designs. Generic design assessment of Hitachi-GE's Advanced Boiling Water Reactor. Assessment report - AR03 Best available techniques.,” Bristol, 2017.

[29] Rolls-Royce SMR, “Sustainability Policy,” 2022.

[30] Rolls-Royce SMR, SMR0002183/002, “Rolls-Royce SMR Generic Design Assessment Scope,” January 2023.

[31] Kerntechnischer Ausschuss (Nuclear Safety Standards Commission) (KTA), “Treatment of Radioactively Contaminated Gases in Nuclear Power Plants with Light Water Reactors (KTA 3605), Safety Standards of the Nuclear Safety Standards Commission (KTA),” 2017.

[32] General Nuclear System Ltd., “UK HPR1000 GDA, Pre Construction Environmental Report, Chapter 3, Demonstration of BAT, Rev 2,” 2021.

[33] NNB Generation Corporate Ltd, “UK EPR Hinkley Point C Radioactive Substances Regulation Permit Application, Chapter 7 Demonstration of Environmental Optimisation,” 2011.

[34] US Nuclear Regulatory Commission, “Radioactive Waste Management Technology Chapter 7: Gaseous Radioactive Wastes, USNRC Technical Training Center, Rev. 0311”.

[35] Rolls-Royce SMR, SMR0000730/001, “KPL Sizing Note,” May 2022.

[36] NUCON International, “NUCON NUSORB Noble Gas Delay Carbons, NUCON Technical Bulletin 11B10,” December 2019.

[37] Rolls-Royce SMR, SMR000746/001, “System Outline Description for the Processing and Treatment System for Gaseous Radioactive Effluent (KPL),” May 2022.

[38] Atkins Ltd., EDNS01000900096/001 , “Gaseous Waste Optioneering Report,” 2020.

9 Acronyms and Abbreviations

ALARA	As Low As Reasonably Achievable
ALARP	As Low As Reasonably Practicable
BAT	Best Available Techniques
BATC	BAT Conclusions
BREF	BAT Reference Document
BSL	Basic Safety Limit
BSO	Basic Safety Objective
BSS	Basic Safety Standards
BSSD	Basic Safety Standards Directive
BWR	Boiling Water Reactor
CAE	Claims Arguments Evidence
CARS	Condensed Air Removal System
CCM	Configuration and Change Management
CE	Chief Engineer
CIV	Civil Structures
DRP	Design Reference Point
DOORS	Dynamic Object Orientated Requirements System
E01	Electrical, Control & Instrumentation
E3S	Environment, Safety, Security and Safeguards
EA	Environment Agency
EOM	Environmental Optioneering Matrix
EPF	Environmental Protection Function
EPR16	Environmental Permitting Regulations (England and Wales) 2016
FA	Forward Action
FMA	Functional Means Analysis
FOAK	First of a Kind
GDA	Generic Design Assessment

GDP	Generic Developed Principles
GWTS	Gaseous Waste Treatment System
HAW	Higher Activity Waste
HAZOP	Hazard and Operability Study
HVAC	Heating, Ventilation and Air Conditioning
IAEA	International Atomic Energy Agency
ID	Identification
IED	Industrial Emissions Directive
ILW	Intermediate Level Waste
LLW	Low Level Waste
MBSE	Model Based Systems Engineering
NM	Nuclear Material
NPP	Nuclear Power Plant
NRW	Natural Resources Wales
NWS	Nuclear Waste Services
ONR	Office for Nuclear Regulation
OPEX	Operating Experience
OSPAR	Oslo and Paris
ORM	Other Radioactive Material
PCD	Preliminary Concept Definition
PSA	Probabilistic Safety Assessment
PWR	Pressurised Water Reactor
R01	Reactor Island
RAG	Red Amber Green
RDS-PP	Reference Designation System for Power Plants
RGP	Relevant Good Practice
RH	Relative Humidity

ROP	RSR Objectives and Principles
RP	Requesting Party
RR SMR	Rolls-Royce Small Modular Reactor
RSR	Radioactive Substances Regulations
SDG	Sustainable Development Goal
SFAIRP	So Far As Is Reasonably Practicable
SG	Steam Generator
SMR	Small Modular Reactor
SMNR	Sustainable Management of Natural Resources
SSC	Structures, Systems and Components
SQEP	Suitably Qualified and Experienced Person
T01	Turbine Island
UK	United Kingdom
UN	United Nations