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2.1 ACRONYMS AND ABBREVIATIONS

The standard project glossary of terms, abbreviations, and plant systems is provided in SMR-300 Plant Breakdown Structure, Acronyms, and Glossary of Terms [1]. The following additional definitions and abbreviations are shown in Table 1.

Table 1: List of Abbreviations and Definitions

Term	Definition
ALARA	As Low As Reasonably Achievable
ALARP	As Low As Reasonably Practicable
AOO	Anticipated Operational Occurrences
Ar-41	Argon-41
BAT	Best Available Techniques
BE	Best Estimate
C-14	Carbon-14
CES	Containment Enclosure Structure
Co-	Cobalt
Cs-	Caesium
CVC	Chemical Volume Control System
DB	Design Basis
DBA	Design Basis Accident
DF	Decontamination Factors
DRP	Design Reference Point
EA	Environment Agency
EE	Expected Event
EPR16	Environmental Permitting (England and Wales) Regulations 2016
EPRI	Electric Power Research Institute
FSAR	Final Safety Analysis Report
GALE	Gaseous And Liquid Effluents
GDA	Generic Design Assessment
GDT	Gas Decay Tanks
GRW	Gaseous Radwaste System
I-	Iodine
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
IRAT2	Initial Radiological Assessment Tool
H-3	Tritium
HEPA	High-Efficiency Particulate Air
HI	Holtec International
HPC	Hinkley Point C
HVAC	Heating, Ventilation and Air Conditioning
Kr-	Krypton
LRW	Liquid Radwaste System
MDA	Minimum Detectable Activity
MoP	Members of the Public
N-16	Nitrogen-16
NRC	Nuclear Regulatory Commission

Term	Definition
NRW	Natural Resources Wales
OPEX	Operational Experience
PCA	Primary Coolant Activity
PC-CREAM 08	Consequences of Releases to the Environment Assessment Methodology
PER	Preliminary Environmental Report
PRIS	Power Reactor Information System
PST	Primary Coolant Source Term
PWR	Pressurised Water Reactor
RCS	Reactor Coolant System
RCV	Radiologically Controlled Ventilation System
RGP	Relevant Good Practice
RN	Radionuclide
RP	Requesting Party
RSR	Radioactive Substances Regulations
SDD	System Design Description
SDG	Sustainable Development Goal
SFP	Spent Fuel Pool
Sr-	Strontium
SRW	Solid Radwaste System
SSEC	Safety, Security and Environmental Case
SZC	Sizewell C
UK	United Kingdom
US	United States
Xe-	Xenon

2.2 INTRODUCTION

Preliminary Environmental Report (PER) Chapter 2 presents quantification information of effluent discharges and the calculations for determining discharge limits for Holtec's generic Small Modular Reactor (SMR)SMR-300. This report comprises Chapter 2 of the generic SMR-300 Preliminary Environmental Report (PER). The PER forms part of the Generic Design Assessment (GDA) for the reactor.

As a nuclear power plant, the generic SMR-300 will produce radioactive materials as waste throughout its lifetime. This waste material will include effluent (aqueous and gaseous) discharges, produced particularly during the operational stage of the plant's 80-year lifetime [2]. This report will consider effluent discharges related to operation of the generic SMR-300 twin-unit plant, including considerations of specific radionuclides (RN) present and abatement or treatment of waste before discharge.

For the purposes of this report and the wider PER, the term "liquid" will be used to refer to aqueous wastes, and doesn't include non-aqueous liquid wastes, which are treated by the Solid Radwaste System (SRW) and are out of scope of this chapter.

This report presents an overview of projected effluent discharges and proposed annual limits to these discharges related to the generic SMR-300 for the current Design Reference Point (DRP) [3], in line with EA guidance on discharge limits. The source term and design-specific information required for estimates in this chapter has been provided by Holtec International (HI). This information was used to calculate predictions of effluent discharges, as described in Section 2.6 Methodology for Estimating Effluent Discharges. The methodology for calculating annual limits to effluent discharges from the generic SMR-300 is described in Section 2.7 Methodology for Determining Limits to Effluent Discharges, including the use of Operational Experience (OPEX).

Comparisons of estimates of effluent discharges from the generic SMR-300 have been made against other relevant operational data from nuclear power stations, and against estimates from previous GDAs (and similar assessments). Information provided on radioactive waste systems in this revision of this chapter is commensurate to the design maturity at time of writing. More detail on these systems is available in the System Design Descriptions (SDD) released as part of the DRP [3].

2.2.1 Purpose

This chapter aims to provide background and methodologies for calculation of quantitative estimates of effluent (aqueous, gaseous (including aerial discharges of airborne particulates)) discharges of radioactive wastes, and to propose realistic limits for these discharges. It will present the results of these calculations and assess the conclusions. These values will be compared to EA guidelines and relevant extant power stations; discharges will be normalised (by power output) to enable relative comparison. The methodologies and comparisons presented in this chapter aim to demonstrate that effluent discharges have been minimised. The resulting source terms and limits in this chapter will be used to inform PER Chapter 3 Radiological Impact Assessment [4], and demonstrate that doses to Members of the Public (MoP) and the environment are As Low As Reasonably Achievable (ALARA).

The specific objectives of this chapter are to:

- Discuss the normal operations source term(s) associated with operation of the generic SMR-300.
- Provide estimates of the quantities and types of effluent discharges to the environment.
- Provide estimates of the effects of radioactive decay and waste treatment built into the generic SMR-300 design on the amount and type of radionuclides that are released to the environment to enable dose assessments associated with PER Chapter 3 [4].
- Propose reasonable permit limits for effluent discharges to the environment, based on the above estimates, allowing for headroom and potential fluctuations in these discharges. Permit limits are determined in line with the EA's "Developing guidance for setting limits on radioactive discharges to the environment from nuclear licensed sites" [5] and Environmental Permitting Regulations (England and Wales) "Criteria for setting limits on the discharge of radioactive waste from nuclear sites" [6].
- Compare these estimated discharges and discharge limits to values from other relevant reactors and relevant sources, recognising and adjusting for different power output ratings.
- Outline the methodologies that will be used to calculate effluent discharges (quantities, radionuclides, and release schedules) as well as discharge limits to the environment, using conservative assumptions to ensure that discharges are safe and realistic.

Aqueous effluents will be discharged via a discharge point as part of the main outfall and gaseous effluents will be discharged via a stack. The number of stacks for the plant has not been finalised. Airborne effluents will be largely filtered by the Heating, Ventilation and Air Conditioning (HVAC) system, and the majority of these wastes will be disposed of as solid wastes, discussed in PER Chapter 1: Radioactive Waste Management Arrangements [7].

2.2.1.1 Tier 2 Deliverables

The following Tier 2 deliverables have been produced in support of this chapter:

- OPEX Selected for PER Chapter 2 Quantification of Discharges and Limits [8].
- Methodology for Calculating Liquid and Gaseous Discharges to Determine Monthly and Annual Levels [9].
- Liquid and Gaseous Discharge Report [10].

The following sections describe the Tier 2 deliverables and how information has been incorporated into this chapter.

2.2.1.1.1 OPEX Selected for PER Chapter 2 Quantification of Discharges and Limits

This report collates effluent discharge data from European, American, and United Kingdom (UK) Pressurised Water Reactors (PWRs), as well as estimated discharge data from previous GDAs and Final Safety Analysis Reports (FSARs) for new nuclear reactor designs. It includes discussion on the criteria used for selecting plants for OPEX.

Section 2.10 of this chapter uses the data in this report to demonstrate that estimated effluent discharges and limits from the generic SMR-300 are comparable to similar plants.

2.2.1.1.2 Methodology for Calculating Liquid and Gaseous Discharges to Determine Monthly and Annual Levels

This report details the methodology used to estimate effluent discharges from the generic SMR-300. It presents normal operations discharge source terms for the reactor, based on calculational methods. The validation methodologies (used to confirm the reliability of the primary methodology) are also presented. A supporting report and three supporting validation spreadsheets are provided as part of this submission.

Section 2.6 discusses the methodologies presented in this submission, and the calculated discharge source terms used to calculate prospective limits for the generic SMR-300 in Section 2.7. Summaries of these discharge source terms are given in section 2.8.

2.2.1.1.3 Liquid and Gaseous Discharge Report

This report discusses the inputs and processing routes and systems for effluent wastes for the generic SMR-300. It includes detailed descriptions of waste streams and flow diagrams for the radwaste systems.

Section 2.5 of this chapter uses this report to discuss the processing routes for effluent wastes, and to discuss inputs and outputs from the radwaste systems.

2.2.2 Scope

This chapter will discuss the summary of methodology and subsequent calculations of radioactive effluent (aqueous and gaseous) discharges from all modes of normal operation during the 80-year operational lifetime of the SMR-300 [2]. It will propose limits for effluent discharges on an annual and monthly basis and compare estimated discharges and proposed limits to similar plants, in accordance with Generic Design Assessment guidance for Requesting Parties [11].

The demonstration that the approach to management of effluent discharges represents Best Available Techniques (BAT) is discussed in PER Chapter 6 Demonstration of Best Available Techniques [12], and is out of scope of this chapter.

Novel aspects of the SMR-300 design, such as the Annual Reservoir, have been considered, but are not anticipated to have a significant effect on the effluent discharges from the reactor. Therefore, the calculations of effluent discharges at this stage of design are not reliant on these novel aspects.

2.2.2.1 Normal Operations

Normal operation is considered to be routine operation (that is, typically, the design basis (DB) or “flowsheet design” and is the minimum level of discharges) and the following are considered to be normal operations [13]:

- Start-up and shutdown.
- Maintenance and testing.
- Infrequent but necessary aspects of operation, for example, plant wash-out.
- Foreseeable deviations from planned operation (based on a fault analysis) consistent with the use of BAT, for example, occasional fuel pin failures in a reactor.

This final bullet is defined as expected events (EEs); these are discussed further in section 2.4.4.1.

Precise calculations of discharge rates and resultant doses documented in PER Chapter 3 Radiological Impact Assessment (RIA) [4] are reliant on specific RN concentrations and forms. The source terms, and methodology for calculating these rates and values for the generic SMR-300 source term isotopes will be discussed in order to present a realistic prediction of the scale of discharges that will be produced.

Relevant radioactive waste management systems (the Gaseous Radwaste system (GRW), the Liquid Radwaste system (LRW) and the HVAC system) are shared by the dual-unit in the SMR-300 [14].

The discharges considered will only be those from routine/normal operations; discharges from accidents or incidents are out of scope of this chapter. See Sections 2.4.4 and 2.4.4.1 for further discussion of normal operations and EEs for the SMR-300. Discharges created during decommissioning are also out of scope of this chapter.

2.2.2.2 Effluent Discharges

Effluent discharges are defined as radioactive aqueous and gaseous releases from the generic SMR-300. Aqueous discharges refers to those that are dissolved in water in the liquid form. They do not include non-water liquid wastes, such as resins or oils.

Gaseous discharges include wastes in gaseous form, airborne particulates and aerosols.

2.2.3 Chapter Structure

This chapter is structured to provide information required for a meaningful GDA assessment. The main structure of this chapter consists of:

- Section 2.1 provides the abbreviations and definitions used within this chapter.
- Section 2.2 introduces the purpose, scope, interfaces, and assumptions of the Quantification of Effluent Discharges and Limits (QEDLs).
- Section 2.3 presents the regulatory context, such as regulatory expectations and requirements, relevant Radioactive Substances Regulations (RSR) principles, and codes and standards, which are considered appropriately in the development of QEDLs.
- Section 2.4 presents the development of the normal operations source term, for use in calculating effluent discharges.
- Section 2.5 describes the processing routes for gaseous and aqueous effluent wastes.
- Section 2.6 presents an overview of the methodologies used for calculating the estimated effluent discharges for the generic SMR-300.
- Section 2.7 describes the methodology for determining limits to effluent discharges for the generic SMR-300, including consideration of headroom factors.
- Section 2.8 presents the estimated effluent discharges from the generic SMR-300, on a monthly and annual basis.
- Section 2.9 presents the proposed discharge limits from the generic SMR-300, on a monthly and annual basis.
- Section 2.10 provides a comparison of the estimated discharges and proposed limits to OPEX from similar plants.
- Section 2.11 summarises this chapter.
- Section 2.12 presents GDA commitments and captured future evidence
- Section 2.13 presents the references used in this chapter.

2.2.4 Interfaces with Other Chapters

Table 2 presents the interfaces between this chapter and other PER and PSR chapters in order to demonstrate this chapter integrates with the Safety, Security and Environmental Case (SSEC).

Table 2: Interfaces with Other Chapters

Chapter Title	Interface
Holtec SMR GDA PER Chapter 1 Radioactive Waste Management Arrangements [7]	PER Chapter 1 presents and provides detail on the management arrangements for solid, liquid and gaseous radioactive waste and spent fuel arising over the lifecycle of the generic SMR-300, providing detail on how the effluents will be generated.
Holtec SMR GDA PER Chapter 3: Radiological Impact Assessment [4]	PER Chapter 3 covers the EA's Initial Radiological Assessment Tool (IRAT2) calculations used for doses from effluent discharges in greater detail than in this chapter and will detail assessments of doses to wildlife and the public. The discharges and limits calculated in this chapter will be used to inform the assessments in PER Chapter 3.
Holtec SMR GDA PER Chapter 5: Approach to Sampling and Monitoring [15]	PER Chapter 5 covers the sampling and monitoring techniques that will be used to measure and record effluent discharges, ensuring they are within the limits to be proposed, for significant radionuclides identified in this chapter. It also considers the detection limits for different radionuclides, which are necessary for determining which radionuclides are suitable performance indicators for the generic SMR-300.
Holtec SMR GDA PER Chapter 6: Demonstration of Best Available Techniques [12]	PER Chapter 6 will demonstrate how the generation and disposal of radioactive waste will be prevented and minimised to reduce the impact on MoP and environment are ALARA, in order to demonstrate that BAT has been applied. PER Chapter 6 covers the BAT claims relating to minimising effluent discharges and doses from these discharges; these claims are out of scope for PER Chapter 2. Relevant associated Claim/Argument in the BAT Chapter: Argument 4.4-A1: Radionuclide Identification and Activity and Limit, and related sub-arguments provide an overview of the relevance of this chapter to the BAT demonstration.
Holtec SMR GDA PSR Part B Chapter 2: Reactor [16]	PSR Part B Chapter 2 covers the fuel and core topic, which is key to defining the forms of source term, which are necessary to quantify effluent discharges.
Holtec SMR GDA PSR Part B Chapter 10: Radiological Protection [17]	PSR Part B Chapter 10 presents and discusses the normal operations source term, which is used to calculate discharge source terms from the generic SMR-300.
Holtec SMR GDA PSR Part B Chapter 11: Environmental Protection [18]	PSR Part B Chapter 11 presents a summary on the scope and conclusions of the PER within the PSR, which will include a summary of the contents and outcomes of PER Chapter 2.
Holtec SMR GDA PSR Part B Chapter 13: Radioactive Waste Management [19]	PSR Part B 13 presents and provides detail on the operations and plant arrangements for solid, liquid and gaseous radioactive waste and spent fuel arising over the lifecycle of the generic SMR-300, providing detail on how the effluents will be generated.
Holtec SMR GDA PSR Part B Chapter 14: Design Basis Accident Analysis [20]	PSR Part B Chapter 14 presents the deterministic analysis for the generic SMR-300 following accident conditions and presents the basis for demonstration that the risk is As Low As Reasonably Practicable (ALARP) in comparison with the numerical targets introduced in this chapter. EEs are discussed in Chapter 14.
Holtec SMR GDA PSR Part B Chapter 23: Reactor Chemistry [21]	PSR Part B Chapter 23 covers the chemistry regimes across the plant systems, which influences the volume, radionuclides present, and form of effluent discharges produced.

2.2.5 Assumptions

The following assumptions pertain to the determination of estimates for liquid and gaseous discharges, their comparison with OPEX, and the subsequent proposal of limits:

- For the purposes of this estimation of radiological discharges it is assumed the reactor is operating at 100% load year-round. This assumption is necessary for the calculation of discharges using the available normal operations source terms and is discussed in more detail in Section 2.4.4.

- In making comparisons to reported OPEX, it is assumed that other operators have grouped RNs for reporting in a similar manner to the SMR-300 (e.g. noble gases, halogens, etc.), so that like-for-like comparisons can be made.
- It is assumed that not all methodologies for calculating, measuring and reporting RNs are the same for all sites and other sources (i.e. GDAs and FSARs) used in the OPEX comparison. For example, different countries have varying methodologies for reporting significant radionuclides when they are below the Minimum Detectable Activity (MDA). This means there will be some uncertainty within comparisons to OPEX.

Assumptions related to the methodologies for calculating discharges are discussed in the deliverable Methodology for Calculating Liquid and Gaseous Discharges to Determine Monthly and Annual Levels [9].

Assessments will be completed in time for updated permit applications to be issued at the decommissioning stage.

2.3 REGULATORY CONTEXT

This section outlines the relevant international and national legislation and policy decisions that a new reactor design must adhere to, in order to protect people and the environment from harm resulting from radioactive discharges.

For the purposes of this GDA, it is assumed that the regulations, codes and standards applied to radioactive waste management, discharges and decommissioning will be those that are currently in force during the development of site permit applications, and that dose limits for MoP will remain unchanged from those in current use in the UK.

2.3.1 GDA Requirements

The EA and Natural Resources Wales (NRW) requirements in the GDA guidance for Requesting Parties [11] related to effluent discharges and limits are outlined in the table below, alongside the sections of this chapter that individual requirements will be addressed within.

Table 3: Summary of GDA Requirements Supporting and Information to be Produced

GDA Requirement	Information as part of GDA
Quantitative estimates of waste arisings for normal operation of: • discharges of gaseous and aqueous radioactive wastes The Requesting Party (RP) should provide its approach to identifying fluctuations, trends and events expected over the lifetime of a facility and for assessing their impacts on discharges and wastes.	PER Chapter 2 Section 2.6 provides information on the methodology for calculating and presenting the discharge of gaseous and aqueous radioactive wastes for normal operations. The supporting Methodology for Calculating Liquid and Gaseous Discharges to Determine Monthly and Annual Levels [9] covers this topic in more detail. Normal operations are defined in Section 2.2.2.1.
For gaseous and aqueous radioactive waste, the RP must estimate the monthly discharges: • on an individual radionuclide basis for significant radionuclides[1] • on a group basis (for example 'total alpha' or 'total beta') for other radionuclides • via each discharge point and discharge route	PER Chapter 2 Sections 2.4 and 2.5 cover the methodology for calculating the source terms, and the discharge routes respectively. SDDs for the Liquid and Gaseous Radwaste systems for the generic SMR-300 have been developed [14].
The radionuclide selection should be consistent with 2004/2/Euratom.	The significant RNs have been selected with reference to 2004/2/Euratom [22] in PER Chapter 2 Section 2.6.5.
Estimates of discharges and disposals should clearly show the contribution of each constituent aspect of normal operations, including: • routine operation (typically, the design basis or 'flowsheet design' and the minimum level of disposals) • start-up and shutdown • maintenance and testing • infrequent but necessary aspects of operation, for example, plant start-up, trips, maintenance, shutdown and refuelling. • foreseeable (based on a fault analysis), unplanned events during normal operation that remain consistent with using Best Available Techniques (BAT), for example, occasional fuel pin or plant failures	Information provided on the radwaste systems in this revision of this chapter is commensurate to the design maturity at the time of writing. Transient source terms (source terms for constituent aspects of normal operations outside of routine operation) are not yet available for this design. A commitment to provide estimates of discharges for each constituent aspect of normal operations has been identified (C_QEDL_100). More detail on these radwaste systems is available in the SDDs released as part of the design reference.

[1] Significant RNs and their selection criteria are discussed in more detail in Section 2.6.5.

GDA Requirement	Information as part of GDA
The RP must support estimates with performance data from similar facilities, where such facilities exist.	Estimates of discharges and limits have been compared to relevant OPEX in Section 2.10. Further information on the selected data and reactors is given in the supporting deliverable OPEX Selected for PER Chapter 2 Quantification of Discharges and Limits [8].
The RP must provide proposed limits for: • gaseous discharges • aqueous discharges • disposal of combustible waste by on-site incineration (if proposed)[2]	Proposed limits are given for gaseous and aqueous discharges in PER Chapter 2 Section 2.9.
The RP must provide proposals for annual site limits (on a rolling 12-month basis) for gaseous and aqueous discharges and must describe how they derived these limits. They can also propose limits to reflect an operating cycle (campaign limits).	The methodology for calculating annual site limits for gaseous and aqueous discharges is given in PER Chapter 2 Section 2.7.

2.3.2 RSR Generic Developed Principles

The RSR principles are a set of guidelines published by the EA to protect people and the environment from the effects of radioactive substances [23].

The principles relevant to the quantification of effluent discharges and limits are as follows:

Table 4: RSR Principles relevant to Quantification of Effluent Discharges and Limits

RSR Principle	Principle as part of GDA
RSMDP3 – Use of BAT to Minimise Waste [24]: BAT should be used to ensure that production of radioactive waste is prevented and where that is not practicable minimised with regard to activity and quantity.	PER Chapter 2 presents an overview of the discharge process for the GRW, HVAC and LRW for the generic SMR-300. The quantification of discharges for the GRW and LRW of the generic SMR-300 is provided in Section 2.8. Discussion of solid wastes and other wastes (e.g. resins and oils) can be found within PER Chapter 1 Radioactive Waste Management Arrangements [7]. The minimisation of these wastes and the application of BAT to this process is covered in PER Chapter 6 [12].
RSMDP12 – Limits and Levels on discharges [24]: Limits and levels should be established on the quantities of radioactivity that can be discharged into the environment where these are necessary to secure proper protection of human health and the environment.	PER Chapter 2 presents the methods for calculating these limits in Section 2.7, and the limits themselves are given in Section 2.9. The dose impact associated with the proposed limits is determined in PER Chapter 3: Radiological Impact Assessment [4] (which assesses impact on the environment and MoP) and PSR Part B Chapter 10: Radiological Protection [17] (which assesses impact on workers, as well as dose from direct radiation).
RPDP1 – Optimisation of Protection [25]: All exposures to ionising radiation of any member of the public and of the population as a whole shall be kept ALARA, economic and social factors being taken into account.	There is a BAT process documented for the plant [26]. Implementation of BAT (as discussed in PER Chapter 6 [12]) should drive the design to achieve exposures that are ALARA.
RPDP4 – Prospective dose assessments for radioactive discharges into the environment [25]: Assessments of potential doses to people and to non-human species should be made prior to granting any new or revised permit for the discharge of radioactive wastes into the environment.	PER Chapter 3: Radiological Impact Assessment [4] presents the methods for assessing exposures to people and non-human species based on discharges at proposed permit levels. Detailed assessments of exposures will be carried out at the site-specific stage, or any future Step 3.

[2] There is no intention to incinerate on site for the generic SMR-300 design, hence these limits will not be proposed [84].

RSR Principle	Principle as part of GDA
ENDP10 – Quantification of discharges [27]: Facilities should be designed and equipped so that best available techniques are used to quantify the gaseous and liquid radioactive discharges produced by each major source on a site.	PER Chapter 2 presents the methodology for quantification of discharges from the GRW and LRW for the generic SMR-300 in Section 2.6. PER Chapter 5 Sampling and Monitoring [15] discusses the techniques used to measure the quantities of effluent radioactive discharges, and BAT is applied as discussed in PER Chapter 6 [12].
DEDP4 – Discharges during decommissioning [28]: Aerial or liquid radioactive discharges to the environment during decommissioning should be kept to the minimum consistent with the decommissioning strategy for the site.	Holtec SMR GDA PSR Part B Chapter 26 [29] presents the decommissioning approach and discharges during this stage, with minimisation of waste generation including discharges to be demonstrated. Discharges during decommissioning are out of scope of PER Chapter 2.

2.3.3 Other Requirements Related to Quantification of Effluent Discharges and Limits

The following key acts, legislations, policies and guidance are relevant to quantification of effluent discharges and limits:

1. Health and Safety at Work etc. Act 1974 [30].
2. The Nuclear Installations Act 1965 [31].
3. Environment Act 1995 [32].
4. Ionising Radiations Regulations 2017 [33].
5. The Environmental Permitting (England and Wales) Regulations 2016 (and amendments) [34] [35] [36].
6. UK policy framework for managing radioactive substances and nuclear decommissioning, May 2024 [37]
7. Department of Energy and Climate Change: Statutory Guidance to the Environment Agency Concerning the Regulation of Radioactive Discharges to the Environment 2009 [38].
8. UK Strategy for Radioactive Discharges 2009 [39].
9. Developing guidance for setting limits on radioactive discharges to the environment from nuclear licensed sites 2005 [5].
10. Environmental Permitting Regulations (England and Wales) Criteria for setting limits on the discharge of radioactive waste from nuclear sites 2010 [40].

The Environmental Permitting Regulation 2016 (EPR16) regulations have specific requirements which are relevant to the quantification of effluent discharges and limits. While dose assessments and evaluations of impact will be covered in PER Chapter 3 Radiological Impact Assessment [4], PSR Part B Chapter 10 Radiological Protection [17] and PSR Part B Chapter 11 Environmental Protection [18], this topic will also consider these requirements, namely:

a) 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.
b) The sum of the doses arising from such exposures does not exceed the individual public dose limit of 1 mSv per year.
c) The individual dose received from any new discharge source does not exceed 0.3 mSv per year.
d) The individual dose received from the discharges from any single site does not exceed 0.5 mSv per year [34].

The sources of international legislation, codes and standards relevant to effluent discharges and limit setting are also considered in the development of this topic which are regarded as good practice, are listed (in no particular order) below, including:

- International Atomic Energy Agency (IAEA), Regulatory Control of Radioactive Discharges to the Environment: General Safety Guide No. GSG-9 [41].
- IAEA, IAEA-TECDOC-1638 "Setting Authorised Limits for Radioactive Discharges: Practical Issues to Consider" [42].
- IAEA, International Basic Safety Standards for Protection Against Ionizing Radiation and for the Safety of Radiation Sources [43].
- IAEA Safeguards – Guidelines for States' Systems of Accounting for and Control of Nuclear Material, IAEA/SG/INF/2 [44].
- Euratom, 2004/2/Euratom Commission Recommendation [22].
- Euratom, Council Directive 2013/59/Euratom [45].
- The US NRC, GALE codes [46].
- The US NRC, NUREG-0017 Revision 2 Calculation of Release of Radioactive Materials in Gaseous and Liquid Effluents from Pressurized-Water Reactors [47].
- ANSI/ANS 18.1 Radioactive Source Term of Light Water Reactors 2020 [48].
- ANSI/ANS 55.4 Gaseous radioactive waste processing systems for light water reactor plants November 1999 [49].
- ANSI/ANS 55.6 Liquid radioactive waste processing systems for light water reactor plants May 2007 [50].
- International Commission on Radiological Protection (ICRP), The 2007 Recommendations of the International Commission on Radiological Protection [51].
- OSPAR Convention, Convention for the Protection of the Marine Environment of the North-East Atlantic (the UK is a signatory to this convention) [52].

Reports 7-11 are US regulatory documents which contain the models/codes which form the basis for the estimates of generic SMR-300 discharges. As discussed in PSR Part A Chapter 5: Summary of ALARP and SSEC [53], "the SMR-300 has been designed against the US legislative framework with a view to global deployment. The design process has taken account of appropriate OPEX and recognition of RGP".

An assessment of the codes and standards used to design the SMR-300 is presented in PSR Part A Chapter 2: General Design Aspects and Site Characteristics [54], with any risks identified to compliance with UK codes and standards identified within individual PSR Part B chapters. The UK-US Regulatory Framework and Principles Report [55] was presented to demonstrate the Requesting Party's understanding of any gaps between the US and UK regulatory regimes, and to identify any work necessary to align the two approaches.

In EA guidance RSR: Principles of optimisation in the management and disposal of radioactive waste [56], it is noted:

Operators may seek to argue that the adoption and implementation of our guidance and relevant good practice represents BAT without the need for more detailed consideration of options appraisal and optimisation. This approach is acceptable, providing that the operator demonstrates that the guidance and good practice is relevant and comprehensive for the facility in question. This approach may be adopted for parts of a facility or all of it depending on the guidance available.

The use of GALE is standard practice for PWRs in the US and formed the basis of estimates used for FSARs, OPEX on discharges and estimates from relevant US plants is presented in section 2.10. Based on the above it is considered that use of these codes are appropriate and consistent with the application of BAT in the UK, subject to evaluation of their performance and results post-GDA. Future evidence (see QEDL_01, Table 20) is recorded to review the outputs from GALE and compare to the validation methodologies, European and international OPEX at the site-specific stage to confirm that GALE represents Relevant Good Practice (RGP) for the generic SMR-300.

On this basis GALE can be regarded as RGP for the SMR-300. Additionally, any results that have been calculated using these standards have been independently validated.

2.3.4 Lessons Learnt and OPEX

OPEX of radiological discharges from comparable operations at other PWR facilities (as the generic SMR-300 design is an evolution of extant PWR designs) have been sourced from the following databases and resources:

Europe:
OPEX from European reactors has been sourced from the European Commission Radioactive Discharges Database (RADD) [57] and the Power Reactor Information System (PRIS) [58].

US:
OPEX from American reactors has been sourced from the United States Nuclear Regulatory Commission (US NRC) Radioactive Effluent and Environmental Reports database [59], PRIS [58] and the Electric Power Research Institute (EPRI) database [60].

UK:
OPEX from UK reactors has been sourced from the EA's Pollution Inventory [61] and PRIS [58].

Data from the above sources has been collated in OPEX Selected for PER Chapter 2 Quantification of Discharges and Limits [8] and used to support the comparison of discharges and limits of relevant facilities against the generic SMR-300.

The estimated discharges and limits from the generic SMR-300 will also be compared to those from previous FSARs and GDA submissions.

Further information on comparisons with OPEX and other datasets is given in Section 2.10, as well as OPEX Selected for PER Chapter 2 QEDL [8].

2.3.5 Sustainability

In accordance with the guidance in The UK Policy Framework for Managing Radioactive Substances and Nuclear Decommissioning [37] and the UK Strategy for Radioactive Discharges [62], effluent discharges must be monitored and kept within limits as defined by the regulations (EPR16), in order to reduce doses to the public and the environment, and to be in line with the United Nations Sustainable Development Goals (SDGs) [63].

The top level plant requirements [64] applied to the generic SMR-300 ensure the application of practical measures to protect the environment and minimise the generation of radioactive waste, embedding environmental sustainability in the design. The overall sustainability approach for the generic SMR-300 is detailed in Holtec SMR-300 GDA Sustainability Strategy [65]. The main aspects from the effluent discharges perspective that contribute to sustainable development in the generic SMR-300 are:

- Radioactive effluent volumes are minimised by plant systems (reuse of primary coolant via the CVC).
- Minimisation of activity in discharges to the environment via abatement of radionuclides (aqueous effluent via the LRW and gaseous effluent via the GRW).
- Discharges to the environment from normal operations and EEs must meet discharge limits that can demonstrate the use of BAT. Below these discharge limits, further reduction is not sought by regulators, although application of BAT is required [34] to ensure a plant is operating sustainably, in order to protect the environment for current and future generations.

2.4 DEVELOPMENT OF A SOURCE TERM FOR ESTIMATING RADIOACTIVE DISCHARGES

2.4.1 Source Term Definition

The ‘source term’ of a nuclear reactor refers to the specific magnitude and mix of RNs present in the plant within the primary system or associated plant systems during normal operations. Source terms are expressed as fractions of fission product inventory in the fuel and contain information about the physical and chemical form and the release time of each RN [66]. It is key to defining the release of ionising radiation, other radioactive wastes and effluent discharges to the environment.

The discharge source terms are reliant on the reactor primary coolant source term (PST). The PST is the specific mix of RNs present in the reactor coolant and is dependent on the core source terms (core isotopes & decay heat and fission products), as well as activation and corrosion products. The PST (and the secondary coolant source term) and the methodology for their derivation are detailed in SMR-300 Contained Radiation Sources for Normal Operation [67]. More detail on this methodology is detailed in Section 2.4.3. This document presents three versions of the PST and the secondary coolant source term: realistic (or best estimate (BE)), DB, and DB with design basis accident (DBA) consideration. The latter two versions are based on heavily conservative assumptions and are primarily used to advise safety-related functions of the generic SMR-300. For realistic estimations of effluent discharges, the realistic source term was used (unless otherwise specified).

The production mechanisms for the RNs in these source terms are discussed below.

2.4.2 Radionuclide Production Mechanisms

The principal sources of RN production during normal operation at power are:

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

Actinides such as Americium, Curium, Neptunium and Plutonium are created by direct and prompt activation in the core by neutron capture of RNs (such as Uranium-238) present in the fuel material, impurities in cladding or trace elements on fuel assembly surfaces deemed tramp uranium.

Neutron activation of various constituents in the primary coolant and air surrounding the core leads to generation of:

- Nitrogen-16 (N-16).
- Tritium (H-3).
- Carbon-14 (C-14).
- Argon-41 (Ar-41).

The majority of radioactive effluent discharges for tritium, carbon-14 and Nitrogen-16 are activated within the primary coolant. Ar-41 is the exception as it is almost wholly produced through neutrons reacting with the air in the containment vessel, with activation within primary coolant negligible. Although N-16 (from neutron activation of Oxygen-16 in the primary coolant) is the predominant RN in the steam generator during operations, it has a very short half-life of 7.1 seconds. Therefore, although it is a significant contributor to the radiation field during operation inside the containment structure (CES), it is not a concern for off-site dose considerations [67], and as such is not considered in the effluent discharge source terms.

Fission products of fissile material in the reactor core can be present in the primary coolant by leakage of fission products through fuel cladding defects. Key fission products generated include (but are not limited to) radioisotopes of:

- Caesium (Cs-).
- Iodine (I-).
- Krypton (Kr-).
- Strontium (Sr-).
- Xenon (Xe-).

Activation products in the reactor coolant are generated from neutron activation of non-radioactive corrosion and wear products that are circulated in the primary circuit. Typical corrosion activated products include (but are not limited to):

- Sodium-24.
- Chromium-51.
- Manganese-54.
- Iron-55.
- Iron-59.
- Cobalt-58 (Co-58).
- Cobalt-60 (Co-60).
- Zinc-65.
- Zirconium-95.
- Silver-110m.
- Tungsten-187.

2.4.3 Development of Normal Operations Source Terms

Core source terms have been developed for the SMR-300 using SCALE 6.2.1 [68] in SMR-300 Source Terms [69]. The Normal Operation primary coolant source terms were then developed from this input data in SMR-300 Contained Radiation Sources for Normal Operation [67]. An overview of this methodology is provided within this section.

2.4.3.1 Development of Contained Radiation Source for Normal Operations

Using the data from SMR-300 Source Terms [69] as input, the sources of contained radiation were determined by propagating the core source term RNs' activity through various plant systems, using parameters and assumptions provided in SMR-300 Contained Radiation Sources for Normal Operation [67], to give a primary coolant source term. The RNs are processed according to the categories assigned in Section 2.4.2, with relevant equations, adjustments, and assumptions detailed in the document.

2.4.3.1.1 Validation of Source Terms

Validation of the Normal Operations source terms was performed in Evaluation of the SMR-300 Calculated Source Terms Against Publicly Available Information [70], to gain confidence in calculations undertaken which depend on the source terms as input data, such as calculations of effluent discharges and limits.

Validation was achieved through comparison of the calculated Normal Operations realistic source term against two datasets: OPEX (source terms from unnamed reference plants from ANSI/ANS-18.1-2020 [48] and other observed data from extant plants), and other calculated source terms (from previous GDAs and FSARs).

The report concluded the following for each group of RNs:

- Fission products: The source term (in both μCi/g and μCi/g/GW) was closely aligned to other calculated source terms, [REDACTED]
- Activated corrosion products: The source term was closely aligned to other calculated source terms, with exceptions explained in the report [70]. [REDACTED]
- Water activation products: The source term for water activation products was low when compared to OPEX for H-3, which was explained by the difficulty in measuring H-3 levels in plants. The source term was closely aligned to other calculated source terms.

[REDACTED] This conclusion indicates that the source term is realistic, but has sufficient conservatism built in to prevent underestimations in further calculations, e.g. discharge levels and dose rates.

2.4.4 Operating Phases

The generic SMR-300 recognises the following standard four operating phases [2]:

1. Start-up Operation: The phase between completion of refuelling and power operation at 100% power, while plant warmup occurs.
2. Power Operation[3]: Steady-state power operation at 100% power. This will be the phase for most of the time that the generic SMR-300 is in operation.
3. Shutdown Operation: The phase between power operation at 100% power and refuelling outage, while plant cooldown occurs.
4. Refuelling Operation: The phase in which spent fuel is removed and fresh fuel is loaded.

The generic SMR-300 is also designed to provide flexible power output and perform load following based on grid demand [2]. This means that the generic SMR-300 is capable of quickly reducing from 100% to 0% power without a plant trip. Full power operation mode will be considered as a bounding case in the calculation of effluent discharges and limits as part of this fundamental assessment however, the impact of load following on radiological discharges will need to be understood in greater detail for future assessments. More information and the potential impact of load following can be found in On load-following operations of small modular reactors [71].

At Step 2 it was recognised that the concept design of the generic SMR-300 did not have additional transient source terms and discharge schedules available for inclusion in a detailed impact assessment of discharge. Specific source terms were not available for load-following operation, EEs, or transient phases of power operation (startup, shutdown etc.). Given these details enable an accurate quantification of discharges and understanding on whether dose to

[3] Referred to as "Normal Operation" in the plant overview; renamed here to avoid confusion with 'normal operations' as defined by GDA guidelines.

the public and non-human biota are ALARA, a GDA commitment has been identified to undertake this work beyond GDA timescales.

C_QEDL_100: Currently the estimates of discharges for the SMR-300 do not reflect the variation in discharges that can take place over the course of the fuel cycle or adequately factor in contributions from unplanned but not unexpected events. A commitment is raised to undertake a detailed assessment of estimated discharge source terms (on an annual and monthly basis) once discharge schedules and process-specific source terms are available, to ensure proposed limits account for the following aspects of normal operation:

a) Start-up and shutdown.
b) Maintenance and testing.
c) Infrequent but necessary aspects of operation, for example, plant wash-out.
d) Load following power operation.
e) Expected events.

2.4.4.1 Expected Events

Derivation of the source term must also include consideration of EEs, defined by the EA as "events that are expected to occur over the likely lifetime of the facility, consistent with BAT" [13]. This includes: "infrequent but necessary aspects of operation; and foreseeable deviations from planned operation (based on a fault analysis) consistent with the application of BAT, for example, occasional fuel pin failures in a reactor" [13]. This is equivalent to the definition of anticipated operational occurrences (AOOs)[4]: "an operational process deviating from normal operations which is expected to occur at least once during the operational lifetime of a facility but which (…) does not (…) lead to accident conditions".

Unlike standard operating phases, EEs may result in discharges higher than those during full power operation. This is because the source term and discharge route may be altered during the EE. As such, full power operation cannot be assumed to be bounding for discharges during EEs. Transient source terms for each EE could be used to calculate greater accuracy of discharges; however, these were not available at the time of assessment. Instead, methodology for calculating effluent discharges and limits has inbuilt factors to account for the impact of EEs. This is discussed in more detail in Methodology for calculating liquid and gaseous discharges to determine monthly and annual levels [9] and in Section 2.6.4.

A comprehensive list of EEs and their causes is given in SMR-300 Event Identification and Classification [72]. The main categories of EEs are as follows:

- Changes to steam flow rates.
- Inadvertent operation or malfunction of Reactor Coolant System (RCS) secondary systems.
- Changes to RCS flow.
- Loss of power/load to the plant.
- Fuel failures or misloads.
- Control Rod mis-operation or malfunction.

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[4] A term used in international and US contexts.

The impact of EEs and other short-term increases in activity concentration on doses to the public and to wildlife will be assessed in the PER Chapter 3 Radiological Impact Assessment [4].

2.5 EFFLUENT PROCESSING ROUTES

2.5.1 Overview

The GRW, HVAC system and LRW have been designed for the management of radioactive effluent and as appropriate treatment/abatement to minimise radioactivity in effluent discharges to the environment. This section discusses the processing systems in place for generic SMR-300 for managing effluent discharges. Detailed description of the discharge routes for radioactive effluents is given in Liquid and Gaseous Discharge Report [10]. The information provided on effluent processing systems in this chapter is commensurate to design maturity in a 2-Step GDA.

Discharges will be sampled and monitored prior to discharge to ensure permit compliance. Systems that process radioactive effluent have sampling & monitoring provisions in place to ensure their effectiveness, and allow diagnostics in the event of elevated discharges. Sampling and monitoring is discussed in more detail in PER Chapter 5: Approach to Sampling and Monitoring [15]. Minimisation of effluent discharges is also discussed in PER Approach and Application to the Demonstration of BAT [26].

Both the aqueous and gaseous processing systems were designed in accordance with ANSI/ANS 55.6 Liquid Radioactive Waste Processing for Light Water Reactor Plants [50] and ANSI/ANS 55.4 Gaseous Radioactive Waste Processing for Light Water Reactor Plants [49].

There is currently no on-site incinerator anticipated for the generic SMR-300 so there are no radioactive discharge routes associated with incineration.

A summary of the effluent processing routes is as follows:

2.5.2 Chemical Volume Control System

The Chemical Volume Control system (CVC) controls the chemical makeup and volume of the primary coolant; this includes regulating the amount of dissolved boric acid (chemical shim) in the coolant to control core reactivity and maintain the desired volume of coolant in the RCS by balancing letdown and charging. The CVC has provisions in the form of a deborating bed demineraliser, reactor coolant cartridge filters, a cation bed and two mixed bed demineralisers to treat primary coolant letdown. Most of the primary coolant letdown to the CVC will be reused as primary coolant; letdown which cannot be reused is sent to the radwaste systems for processing and disposal. Liquid and Gaseous Discharge Report [10] contains further details about the CVC.

2.5.3 Gaseous Effluent Processing Routes

Detail of the processing of gaseous and airborne discharges is discussed in PER Chapter 1 RWMA [7] and in Liquid and Gaseous Discharge Report [10].

2.5.3.1 Gaseous Radwaste System

The GRW is designed to process gaseous waste generated during normal plant operation.

The processing of gaseous effluent within the GRW is initiated manually from the GRW control board and operations terminate when pre-set criteria (e.g. high or low tank pressure, tank liquid level, release gas activity, etc.) are met.

The bulk of the radioactive gases processed by the GRW have relatively short half-lives, hence, decay is an important mechanism. The processing of the gaseous waste is through the GDTs, which store gases to provide sufficient decay prior to release into the environment via the RCV, which transfers the gaseous waste to the plant vent stack. Gases may also be immediately reused in effluent holdup tanks of the CVC as a cover gas to preclude air intrusion.

The system provides holdup for decay of radioisotopes in gas decay tanks (GDTs) and transfers processed gaseous effluent either for reuse as cover gas in the CVC, or to the Radiologically Controlled Ventilation System (RCV) for release via the stack.

A simplified flow diagram of processing in the GRW is given in Figure 1.

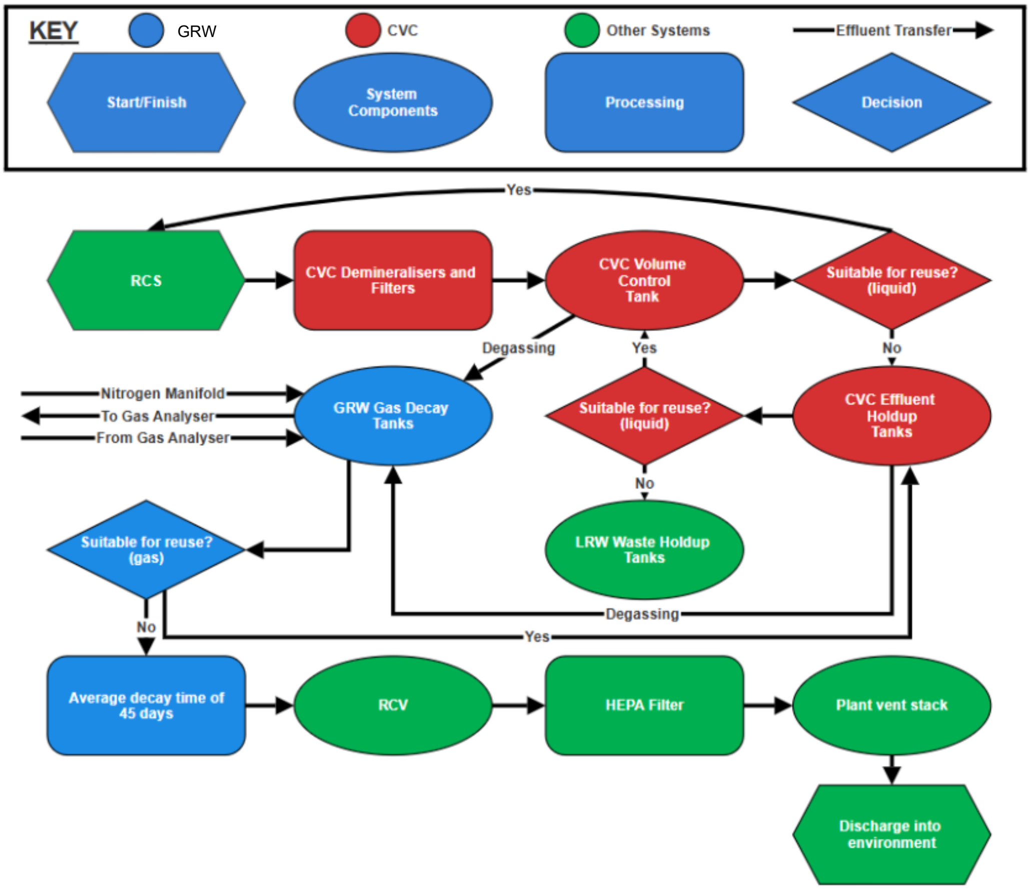

Figure 1: Flowchart of Simplified Effluent Processing in the GRW

2.5.3.2 Heating, Ventilation and Air Conditioning Systems

The HVAC Systems have multiple functions within the generic SMR-300 design. For radioactive effluents, the HVAC will employ high-efficiency particulate air (HEPA) filters to remove airborne particulates and charcoal filters to remove gaseous radioiodine.

HVAC Systems will be employed in the RCV and the Containment Building Ventilation System (CBV). All processed gaseous and airborne effluents will be vented to the atmosphere via the stack.

2.5.4 Aqueous Effluent Processing Routes

Detail of processing of aqueous discharge is discussed in PER Chapter 1 RWMA [7] and in Liquid and Gaseous Discharge Report [10].

2.5.4.1 Liquid Radwaste System

The aqueous waste directed into the LRW is stored in waste holdup tanks until processing occurs. The processing of waste is achieved through a number of components in the system described in the LRW SDD, used as required, depending on the type of waste:

- A pre-filter: a stainless-steel filter which collects particulate matter from the waste stream prior to processing through ion exchangers. It is disposable, provided with isolation valves and a bypass line.
- An activated carbon filter: a deep-bed filter to remove potential residual oil from the Radioactive Drains System (RDS) floor wastes and other non-ionic contaminants from CVC letdown.
- Three ion exchangers: identical vessels arranged in series and selectively loaded with resin, depending on plant conditions and waste needs. The order of ion exchangers can be interchanged to provide complete usage of the ion exchange resin to minimise solid waste generation.
- An after-filter: provided downstream of the ion exchangers, it collects particulate matter, such as resin fines. This stainless-steel filter is cartridge type and is provided with isolation valves and a bypass line.

The LRW is designed to meet the requirements for RN concentration for releases of aqueous effluents to the environment, ensuring BAT is applied, before release to the environment.

A simplified flow diagram of processing in the LRW is given in Figure 2.

Figure 2: Flowchart of Simplified Effluent Processing in the LRW

2.6 METHODOLOGY FOR ESTIMATING EFFLUENT DISCHARGES

Estimation of effluent discharges has been conducted and validated in the report Methodology for Calculating Liquid and Gaseous Discharges to Determine Monthly and Annual Limits [9]. This report discusses the primary methodology, as well as validation methodologies and some comparisons to OPEX for groups of discharges. A summary of the primary methodology is below.

2.6.1 Overview

The primary methodology for estimating effluent discharges and limits from the generic SMR-300 was conducted using the Gaseous And Liquid Effluent - PWR (GALE-PWR) 3.2 Code, with results and a detailed description of the methodology in the report Estimate of the SMR-300 Gaseous and Liquid Effluent Releases using the GALE-PWR 3.2 Code [73]. The majority of RNs taken into account in the methodology below are described in section 2.6.3:

1. Reactor-specific values (SMR-300 design parameters) are input into the GALE-PWR 3.2 code. These values have been derived from SDDs and design calculations from the SMR-300 current DRP. Where no design information was available, values were determined using relevant documentation (NUREG-0017 [74] [47] and ANSI standards [48] [49] [50]), including values for RN half-lives.
2. The parameter file for the GALE-PWR 3.2 code was edited, using NUREG-0017 [47] and SDDs and design calculations from the SMR-300 design.
3. The output results from the GALE-PWR 3.2 code were post-processed, with cutoff points for activity reporting edited, and units converted from Imperial to SI.

It was determined that the use of GALE, which is widely used in the US for assessment of radiological discharges in accordance with US national standards, represents RGP for the generic SMR-300 and consistent with the application of BAT, when operated by Suitably Qualified and Experience Personnel. Discussion of the suitability of US codes is discussed further above, in Section 2.3.3.

2.6.1.1 Decontamination Factors

Decontamination factors (DFs) are the ratio of activity prior to and after the decontamination applied by equipment used to treat radioactive waste. The factors used in this methodology are from the NRC's NUREG-0017, Revisions 1 and 2 [74] [47] – the underlying code for GALE-PWR 3.2.

2.6.1.2 Fractions of Primary Coolant Activity

The radioactivity input to the liquid radwaste treatment system is based on the flow rates of the liquid waste streams and their radioactivity levels, expressed as a fraction of the primary coolant activity (PCA). The default values for the fractions of PCA in each waste stream are based on the recommendations of ANSI/ANS-18.1 [75]. GALE-PWR 3.2 allows inputs to be allocated a fraction of the PCA to represent the fraction of activity within the PST that would be expected in that waste stream.

2.6.1.3 Decay Factors

Radioactivity decays exponentially in relation to time, following the equation:

$$A = A_0 \cdot e^{-\lambda t}$$

Where:

A = the final activity

A_0 = the activity at t = 0

e = Euler's number; the base of the natural logarithm

λ = the decay constant for a given radionuclide

t = the time that a radionuclide is decayed over

Each RN has a fixed decay constant, which is built into the GALE-PWR 3.2 Code. The time that effluents will be present in the system is modelled in the program, and the decay constant applied over that time.

2.6.2 Inputs

The generic SMR-300 produces several waste streams that are processed through the LRW, GRW and HVAC systems. All parameter inputs are detailed in [73].

2.6.3 Radionuclides Evaluated using Alternative Methodologies

The above methodology (use of the GALE-PWR 3.2 Code) is not considered applicable to H-3, C-14 or Ar-41, due to their production mechanisms and distribution in nuclear plants being significantly different to other RNs assessed. The alternative methodologies for C-14 and Ar-41 are discussed in more detail in Estimate of the SMR-300 Gaseous and Liquid Effluent Releases using the GALE-PWR 3.2 Code [73]. It was not identified that an alternative methodology was necessary for H-3 until the results were validated in Methodology for Calculating Liquid and Gaseous Discharges to Determine Monthly and Annual Limits [9]; a GDA commitment has been identified to capture planned work for both H-3 discharges and Ar-41 discharges (see below).

C_QEDL_101: The current methods for determining discharges associated with Tritium and Argon-41 are overly conservative due to uncertainty relating to design information available for a 2-Step GDA. A Commitment is raised to ensure revised methodologies for calculating discharges of Argon-41 and Tritium are developed once the design has matured to a level at which reactor-specific values can be used to remove conservative assumptions.

2.6.3.1 Tritium

H-3 discharges were initially assessed using the primary methodology set out in Section 2.6.1, with the GALE-PWR input being modified to the SMR-300 specific value of 0.323 μCi/g (12.0 MBq/kg), as discussed in Estimate of the SMR-300 Gaseous and Liquid Effluent Releases using the GALE-PWR 3.2 Code [73]. During validation of these results in Methodology for Calculating Liquid and Gaseous Discharges to Determine Monthly and Annual Limits [9], it was determined that the results for H-3 (specifically gaseous H-3) were considerably higher than OPEX ranges and previous GDA predictions.

In Evaluation of SMR-300 Calculated Source Terms Against Publicly Available Information [70], it was noted that H-3 levels are difficult to quantify due to H-3's potential for dispersal, and being prevalent in multiple phases/forms. However, this report also concluded that the estimated realistic SMR-300 primary coolant source term for H-3 was lower than average for both OPEX and other reactor design calculations.

Given this inconsistency, it was concluded that the GALE-PWR code's assumptions are excessively conservative for the determination of H-3 discharges. [REDACTED]

In the absence of any clear US PWR design differences to account for this delta, it is likely as a result of different approaches in tritium management between the US and European/UK plants. Tritium waste management strategies—both for LRW and GRW—include specific design features and operational preferences, such as whether to discharge or recycle effluents. These decisions significantly influence actual tritium releases. Additionally, tritium production in the reactor coolant can be influenced to some extent by water chemistry, particularly the concentrations of boron and lithium used during operation, again dependent on operator approach [76], [77].

Additionally, observed differences in tritium discharges between US and European PWRs may also reflect differences in regulatory frameworks. For example, European regulations often emphasize minimizing discharges "as low as reasonably achievable" (ALARA), while US regulatory guidance can focus on dose-based limits. According to the EPRI Tritium Management Model [77]:

Historically, the exposure associated with US tritium releases is a small fraction of the exposure limits established under the guidance of 10CFR20 Appendix I. Based on this information, tritium remains an isotope of minimal biological risk or environmental consequence."

These differences in regulatory philosophy and dose assessment approaches could also contribute to the variation in reported H-3 discharges between US and European PWRs.

As the GALE-PWR estimates are based on this US OPEX data, this likely accounts for the significant difference between predicted H-3 discharges for the generic SMR-300, and existing OPEX plants in Europe.

In order to provide a more realistic assessment of tritium discharges for the generic SMR-300, it was concluded that the methodology will be reviewed and revised. Therefore, commitment C_QEDL_101 has been raised to capture the commitment to revising the methodology for H-3 to give a more accurate estimation of discharges in line with tritium management practices in the UK consistent with the application of BAT. Future evidence is recorded for the site-specific stage to develop a tritium management strategy for the generic SMR-300 that supports the demonstration of the use of BAT (see QEDL_02, Table 20: Future Evidence).

It is also acknowledged that the inclusion of secondary neutron sources in the design of the generic SMR-300 has the potential to impact discharges of H-3 and will need to be adequately considered in any refined assessment once design maturity allows. Secondary neutron sources are typically incorporated into the design as part of some fuel assemblies, to ensure generation of enough neutrons for a self-sustaining fission reaction. They are typically required for initiating the fission reaction in PWRs for the initial fuel cycles, until such time that decay of irradiated fuel provides enough additional neutrons to initiate a sustainable fission reaction, at which point consideration can be given to removal of the secondary sources.

For PWRs in the UK (Sizewell B and the design of Hinkley Point C/Sizewell C) typically these have been made of a combination of Antimony-Beryllium, and when activated is a source of additional tritium within the reactor core, which would need to be factored into estimations of tritium discharges. Given current design maturity there is not sufficient information on the design of secondary neutron sources for the generic SMR-300 to allow estimation of their impact on discharges, an evaluation will be undertaken post-GDA timescales (see QEDL_03 Table 20: Future Evidence).

2.6.3.2 Carbon-14

C-14 cannot be accurately estimated with the primary methodology, as it is produced through neutron-induced reactions with stable isotopes found in the air (as well as structural materials and cladding), as well as in the core or coolant (where most other RNs are primarily produced) [78].

As it was determined that C-14 could not be accurately estimated with the GALE-PWR 3.2 code, discharges from the generic SMR-300 were evaluated using an estimated SMR-300 specific value of 3.8 Ci/yr (141 GBq/yr) - a thermal-output based adjustment to the average general PWR value of 3.65 µCi/GWth (135 kBq/GWth) per year from EPRI Report Estimation of Carbon-14 in Nuclear Power Plant Gaseous Effluents [78]. The results of this methodology were validated in Methodology for Calculating Liquid and Gaseous Discharges to Determine Monthly and Annual Limits [9] and deemed to be accurate for the generic SMR-300.

2.6.3.3 Argon-41

Similarly to C-14, Ar-41 is not adequately estimated with the GALE-PWR 3.2 code, as it is also formed by neutron activation of stable isotopes in the air.

Ar-41 discharges from the generic SMR-300 were evaluated using an estimated release rate of 6 Ci/yr (222 GBq/yr) Applicability of GALE-86 Codes to Integral Pressurized Water Reactor Designs [79]. This value is given as a bounding value for all PWR designs and is primarily dependent on the volume of containment air[5]. As the generic SMR-300 sites will be significantly smaller than a traditional PWR, this value is considered to be maximally bounding for the generic SMR-300. When this result was compared to OPEX and previous GDA values in Methodology for Calculating Liquid and Gaseous Discharges to Determine Monthly and Annual Limits [9], it was found to be much higher than the EU and GDA ranges, likely due to this difference in volume of air on site. Therefore, commitment C_QEDL_101 will also include revision of the methodology for Ar-41 to give a more accurate estimation of discharges.

2.6.4 Operating Conditions and Consideration of Expected Events

The operating conditions considered in the quantification of discharges and limits are all the constituents of normal operation (as specified in Section 2.2.2.1) including start-up, shutdown and maintenance as well as EEs. For all of normal operations with the exception of EEs, for the purposes of estimations of effluent discharges it was assumed the reactors operate at full

[5] When compared to OPEX in Methodology for Calculating Liquid and Gaseous Discharges to Determine Monthly and Annual Limits [9], this value was found to be slightly below the US PWR mean, but much higher than the EU mean and previous GDA estimates. Therefore, despite not being strictly bounding for all PWRs, this value is still considered bounding for the generic SMR-300, due to the size of the plant.

power all year; however, further work will be required to determine how load following could impact short term and long-term discharges.

EEs, as described in Section 2.4.4.1, will result in a change in activity in short-term discharges. The GALE-PWR 3.2 code does not have the functionality to calculate the effect of individual EEs on gaseous and aqueous discharges. To mitigate for this, it uses a database of OPEX from extant PWRs to calculate an AOO[6] coefficient: an amount of activity weighted by thermal power rating that is added to the calculated discharges, in proportion to the relative activities of RNs. This approach is functionally an average of discharges with regards to the frequency of different EEs; different EEs may increase different RN discharges disproportionately compared to the full power operation discharge source term. It is also not bounding, as it considers the average increase in discharges due to EEs rather than the effect of individual events. For example, in a year that contained more EEs than the average year, this coefficient would underestimate the total discharge. Given that these events occur relatively infrequently any given short-term impact on an annual permit limit of the event occurring would be significantly underestimated. This coefficient is applied prior to any headroom factors, which will be applied separately to individual EE source terms (as well as other normal operations source terms) once these are available (see C_QEDL_100).

2.6.5 Determination of Significant Radionuclides

According to GDA guidance for Requesting Parties [11], significant RNs are those which:

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

EA guidance [13] recommends a series of criteria to select significant RNs that:

a) are significant in terms of radiological impact on people (the dose to the most exposed group at the proposed limit exceeds 1 µSv per year).
b) are significant in terms of radiological impact on non-human species (where the impact on reference organisms from the discharges of all radionuclides at the proposed limits exceeds 40 µGy/hour).
c) are significant in terms of the quantity of radioactivity discharged (the discharge of a radionuclide exceeds 1 TBq per year).
d) may contribute significantly to collective dose (where the collective dose truncated at 500 years from the discharges of all radionuclides at the proposed limits exceeds 1 man-sievert per year to any of the UK, European or World populations).
e) are constrained under national or international agreements or is of concern internationally.
f) are indicators of plant performance, if not otherwise limited on the above criteria.

[6] EEs, the term adopted for the generic SMR-300 (in line with EA guidance), are consistent with the US NRC definition of AOOs, with the one caveat to this being that EEs remain consistent with the use of BAT [13].

g) for the appropriate generic categories from the RSR Pollution Inventory (e.g. “alpha particulate” and “beta/gamma particulate” for discharges to air) to limit any radionuclides not otherwise covered by the limits set on the above criteria.

RNs significant under criteria a) and b) were determined using the IRAT2 tool [80], which is discussed in more detail in PER Chapter 3: Radiological Impact Assessment [4] and the RIA Topic Report [81].

RNs significant under criterion c) were determined by analysis of the discharged source terms, detailed in Section 2.8.

RNs significant under criterion d) were determined using the Consequences of Releases to the Environment Assessment Methodology (PC-CREAM 08) tool [82], which is discussed in more detail in PER Chapter 3: Radiological Impact Assessment [4] and the RIA Topic Report [81].

No RNs were identified as significant under criterion e). Relevant international treaties and agreements have been considered (see section 2.3.3). There are general obligations for participating nations to reduce discharges of certain radionuclides of concern under both the OSPAR Conventions [52], and IAEA [44]; however, these either don’t specify radionuclides of relevance to the PST of the generic SMR-300, or do not specify constraints at a site-level.

RNs significant under criterion f) have been identified through system analysis. Noble gases and halogens can indicate fuel failure or fuel water leakage. Halogens and particulates can indicate failures in the HVAC and GRW systems.

The total doses indicated through initial IRAT2 assessment indicate that the total discharges from the generic SMR-300 will be below the threshold of significance for criterion g).

According to application of the above criteria, a list of significant RNs has been created. The significant RNs and their criteria and methods for selection are described in Table 5 below.

Consideration was also given to 2004/2/Euratom [22], which indicates key RNs and detection thresholds for these RNs. All key radionuclides identified as relevant to PWRs in 2004/2/Euratom were cross-checked against significant radionuclides identified via the criteria above and nothing additional was identified, except for alpha emitters which have not been identified as significant given historical measurements carried out at OPEX PWRs have consistently indicated that discharges are below detection levels.

Table 5: Significant Radionuclides Selected for the Generic SMR-300

EA criterion selected for	Selected RN(s) (Gaseous)	Selected RN(s) (Aqueous)	Method for Determination	Additional Information
a) Dose to most exposed group at the proposed limit exceeds 1 μSv per year.	H-3, C-14, Ar-41[7]	H-3, C-14, Cs-134[8], Cs-137	IRAT2 used to calculate doses from gaseous and aqueous effluents at projected limits. Detail of this assessment can be found in the RIA Topic Report [81] and PER Chapter 3 [4]	Aqueous H-3, Cs-134 and Cs-137 are above the 1 μSv per year cut-off solely for a lakeside site model. This model and associated significant radionuclides will be reconsidered at the site-specific stage if a lakeside site is of relevance to the SMR-300; a future evidence is recorded in Table 20
b) Impact on reference organisms from the discharges of all radionuclides at the proposed limits exceeds 40 μGy/hour.	None	C-14	IRAT2 used to calculate doses from gaseous and aqueous effluents at projected limits. Detail of this assessment can be found in the RIA Topic Report [81]and PER Chapter 3 [4].	Aqueous C-14 is above the 40 μGy/hour cut-off solely for a lakeside site model. As above, this model and significant radionuclides will be reconsidered at a later stage, see Table 20.
c) Discharge of a radionuclide exceeds 1 TBq per year.	H-3	H-3	Releases were calculated in Estimate of the SMR-300 Gaseous and Liquid Effluent Releases using the GALE-PWR 3.2 Code [73].	N/A
d) Collective dose truncated at 500 years from the discharges of all radionuclides at the proposed limits exceeds 1 man-sievert per year to any of the UK, European or World populations.	C-14	None	PC-CREAM 08 used to calculate doses at 500 years to all relevant populations using the discharged source term.	N/A
e) Are constrained under national or international agreements or is of concern internationally.	None	None	The sources of international legislation, codes and standards relevant to effluent discharges and limit setting (see Section 2.3.3) have been considered, specifically the OSPAR convention [52] and IAEA-TECDOC-1638 [42].	No international agreements identified relevant to generic SMR-300 discharges, or that set site-level constraints. Radionuclides of interest identified in OSPAR have already been considered under other criteria

[7] The > 1 μSv dose as a result of Ar-41 is based on an effective stack height of 0 m for the Stage 2 RIA (See PER Chapter 3 [4]), and the resultant dose per unit release is likely to be considerably lower following the Stage 3 assessment using specific stack height parameters during detailed design. Therefore, it is currently assumed it will be captured under the “Noble Gases” grouping, rather than a radionuclide-specific limit being proposed. This will be confirmed appropriate following the Stage 3 assessment (see QEDL_04, Table 20: Future Evidence).

[8] Cs-134 & Cs-137 were only identified as significant via criterion a) for a lakeside site model. Cs-137 has already been identified as significant for liquid discharges via criterion f). Cs-134 is currently not being taken further as a proposed radionuclide for an individual limit given its’ significance only in the lakeside scenario. This will be reconsidered at the site-specific stage in the event a lakeside site is selected (see QEDL_05, Table 20: Future Evidence).

EA criterion selected for	Selected RN(s) (Gaseous)	Selected RN(s) (Aqueous)	Method for Determination	Additional Information
f) Indicators of plant performance.	Kr-85, Co-60, Xe-133, I-131	Co-60, Cs-137	Noble gases (Kr-85 and Xe-133) and halogens can indicate fuel failure or fuel water leakage. Halogens and particulates can indicate failures in the HVAC and GRW systems.	Ni-63 is also a RN that indicates plant performance (notifying of build-up in plant systems), and is often present in OPEX. However, it is not present in the PST [69], so levels in effluent cannot be assessed. While all halogenic RNs can be used to indicate plant performance, I-131 is the most radiologically significant RN and the easiest to measure. Halogenic RNs are processed similarly in the primary and waste treatment systems, therefore it is appropriate to use I-131 as a proxy or representative for the whole RN group. Co-60 is considered a useful indicator specifically of excess corrosion products in discharges, and a future evidence has been defined to consider the benefits of an individual limit for Co-60 (see Table 20: Future Evidence), currently it is measured within the 'Others' grouping for both liquid & gaseous discharges.
g) For the appropriate generic categories from the RSR Pollution Inventory	N/A	N/A	N/A	The dose from other RNs not covered by the above categories is assessed to be under 1 μSv per year collectively through the IRAT2 tool and are therefore not considered significant.

In selecting significant RNs, the requirements of EC/Euratom/2004 [22] have also been considered. The RNs selected by the above criteria are consistent with the RNs listed in this source. These RNs and their production mechanisms and forms are summarised in Table 6.

Table 6: Summary of Significant Radionuclides for the Generic SMR-300, with Forms and Production Mechanisms

Radionuclide	Aqueous/Gaseous/Both	Production Mechanism
H-3	Both	Neutron activation in reactor coolant
C-14	Both	Neutron activation in reactor coolant
Ar-41	Gaseous	Neutron activation in air within containment building
Co-60	Both	Activation of corrosion products in reactor process systems
Kr-85	Gaseous	Leakage of fission products from minor fuel defects
I-131	Gaseous	Leakage of fission products from minor fuel defects
Xe-133	Gaseous	Leakage of fission products from minor fuel defects

Radionuclide	Aqueous/Gaseous/Both	Production Mechanism
Cs-134[9]	Aqueous	Leakage of fission products from minor fuel defects
Cs-137	Aqueous	Leakage of fission products from minor fuel defects

Although the RNs in Table 6 have been determined to be significant from the methodology used in Table 5, it would be impracticable to determine specific discharge limits for all these RNs. Therefore, for the RNs discharged, limits are proposed both individually and grouped according to similarities in how they are generated, managed, abated and monitored. In making the individual RN and grouping decisions for setting limits previous RSR permits, applications for permits and GDAs have also been reviewed.

When considering grouping of the RNs applicable for setting limits for the generic SMR-300, the following points have been considered:

1) The suitability of a single RN for substituting as a representative or 'proxy' for a group of RNs that it belongs to:
    a. I-131 is the most radiologically significant RN within the halogen group and is representative of the whole group, given that all halogens have a similar chemical behaviour in the primary effluent and the waste treatment systems. A limit on I-131 alone is considered adequate for control of the discharges of all halogenic isotopes and the exposures from such discharges given that it is easy to detect as it has a longer half-life relative to other halogens of significant activity present in the PST. Other halogens will not have discharges or limits reported in this chapter, as they are represented by I-131.This approach is consistent with the limits set by Sizewell B, the operating PWR in the UK.
2) From an aqueous effluent standpoint, Cs-137 is an indicator of fuel integrity and due to its solubility, it is highly mobile in the aqueous radwaste system and easily measured (via gamma spectrometry) at very low levels of detection. It has a relatively long-half life, so as well as giving indications of fuel leaks in the primary circuit or spent fuel pool (SFP), it can also be used to measure resin abatement system performances. As such, the quantity of Cs-137 in liquid discharges is regarded as one of the best readily measurable indicators of fuel and plant performance. In addition to this, Cs-137 is persistent in the environment with a lengthy half-life of 30 years. Therefore, it was deemed appropriate to set an individual limit for Cs-137.
3) It is not necessary to set individual limits for certain significant RNs, when they do not contribute significantly to dose, are better considered collectively (such as noble gases or gaseous particulates) or can be represented by other RNs:
    a. Gaseous particulates not regarded as significant either in terms of activity discharged or contribution to the total gaseous discharges for the generic SMR-300. While some (e.g. Co-60) can be used as indicators of plant performance, there is no advantage to monitoring any beta/gamma emitting

[9] Cs-134 & Cs-137 were only identified as significant via criterion a) for a lakeside site model. Cs-137 has already been identified as significant for liquid discharges via criterion f). Cs-134 is currently not being taken further as a proposed radionuclide for an individual limit given it's significance only in the lakeside scenario. This will be reconsidered at the site-specific stage in the event a lakeside site is selected (see QEDL_05, Table 20: Future Evidence).

particulate RN individually, so they can be grouped with other beta/gamma emitting particulate RNs for limit-setting and performance monitoring purposes.

b. Aqueous Cs-134, which is also identified as one of the significant RNs for the generic SMR-300 due to its dose contribution in the lakeside model, provides all the same characteristics as Cs-137 (see above). However, its half-life is significantly shorter, making it less persistent in the environment and unnecessary for an individual limit, as Cs-137 can be used as a reliable indicator of fuel integrity and system performance. Additionally, as it is only radiologically significant for the lakeside model (and not in any other modelled discharge scenario), an individual limit for Cs-134 will not be proposed. Cs-134 will be grouped with other beta/gamma emitting particulate RNs for limit-setting purposes, with this to be reviewed at site-specific stage dependent on the site (see QEDL_05, Table 20: Future Evidence).

c. Aqueous Cobalt-60 was considered but not included for a specific annual limit at this stage. It meets the criteria of a significant RN, but its contribution to dose is minimal. It is noted that Co-60 in aqueous discharges is potentially a useful indicator of issues relating to corrosion in the primary circuit, as such it should be considered at the site-specific stage (see QEDL_06, Table 20: Future Evidence). Currently Co-60 has been included with the other beta/gamma emitting particulate RNs.

d. Strontium-90 is a potential indicator of issues with fuel integrity and identified as a key radionuclide within 2004/2/Euratom, however as it does not fulfil other criteria, and is significantly less reliable to detect compared to CS-137, it has not been selected as a significant for an individual limit. It will be grouped with other beta/gamma emitting particulate RNs for limit-setting purposes, and will be monitored primarily in bulk aqueous effluent samples.

4) Alpha activity has not been considered significant or proposed for a limit, as historical measurements carried out at PWRs have consistently indicated that discharges are below detection levels.

Taking the above points into consideration the specific individual RNs and groupings have been determined for gaseous and aqueous discharge limits in Table 7.

Table 7: Radionuclides/groups selected for discharge limits

Gaseous	Aqueous
H-3	H-3
C-14	C-14
I-131	Cs-137
Noble gases (limit expressed as '**Noble Gases'**); comprising isotopes of: • Argon (Ar-41) • Krypton (Kr-83m, Kr-85m, Kr-85, Kr-87, Kr-88, Kr-89) • Xenon (Xe-131m, Xe-133m, Xe-133, Xe-135m, Xe-135, Xe-137, Xe-138)	**Other Radionuclides** (Other Beta/Gamma emitting particulate RNs and halogenic RNs)
Beta-emitting Radionuclides associated with particulate matter (Other Beta/Gamma emitting RNs)	

Limits for the groups ‘Beta-emitting Radionuclides associated with particulate matter’ and ‘Other Radionuclides’ are limits to the activity of all RNs listed in the discharge source terms calculated in Estimate of the SMR-300 Gaseous and Liquid Effluent Releases using the GALE-PWR 3.2 Code [73] that fulfil the description given in the table.

The groupings determined at this stage could be modified subject to the application of BAT on a finalised design before site specific stage.

2.7 METHODOLOGY FOR DETERMINING LIMITS TO EFFLUENT DISCHARGES

2.7.1 Overview

GDA guidance for Requesting Parties [11] states that the RP must provide proposed annual site limits (on a rolling 12-month basis) for gaseous discharges and aqueous discharges, and the methodology for deriving these limits must be described. It will need to be demonstrated that discharges at these limits will comply with the relevant UK dose limits and constraints, that the impact of the facility is ALARA in terms of radiation exposure to the public, and discharge to the environment. The limits and method proposed at GDA will likely be refined at the site-specific stage to proposed limits for any future RSR permit application.

2.7.2 Headroom Factors

Different operational stages for the generic SMR-300 involve different processes, and discharges of effluent RNs will fluctuate accordingly. Headroom factors are utilised to ensure that discharge limits are sufficient to allow for normal operation discharge fluctuations without breaching the limits. EA guidance [5] states that discharge limits should be set so as to minimise the 'headroom' between the actual levels of discharge expected during normal operation and the limits themselves, so the headroom factors are calculated to be as accurate as possible to estimated operational fluctuations in order to prevent excess conservatism.

These headroom factors are usually generated by looking at the average fluctuation in discharges for a particular RN or RN group. For the generic SMR-300, there is no fleet data to base these headroom factors on, so instead OPEX [8] is used to work out the average headroom factor for each RN, with a simple statistical approach.

Typically, whether headroom factors are applied prior to the addition of contributions from expected events (*(routine discharges x headroom) + expected events)* or after (*(routine discharges + expected events) × headroom)* is dependent on whether EEs are calculated theoretically, or based on OPEX. Headroom factors will therefore be reconsidered for future assessment once EEs have been fully considered (See C_QEDL_100).

Headroom factors for the generic SMR-300 have been calculated using OPEX [8], according to the following method:

1. The mean and standard deviation for discharges of each RN in Bq is calculated across a ten-year period for the plants analysed in OPEX [8]. Zero values (i.e. years where no discharge of a RN is recorded) are excluded from these calculations, in order to present a pessimistic estimation of average discharge, to ensure that headroom factors will be calculated conservatively.
2. The following groups of RNs were created (see Table 7) for effective calculation of headroom factors:
    a. Tritium (aqueous and gaseous)
    b. Carbon-14 (aqueous and gaseous)

c. Iodine-131[10] (gaseous)
d. Noble Gases (gaseous)
e. Caesium-137 (aqueous)
f. Other Beta/Gamma emitting RNs (referred to as 'Other RNs' for aqueous discharges and 'other beta-emitting RNs associated with particulate matter' for gaseous discharges)

3. A k-value of 3.09 times the standard deviation, corresponding to a confidence interval of 99.9% (see Table 8 for a summary of k-values and confidence intervals), was applied to the mean of the discharges using the following equation to calculate the headroom factor:

$$HF = \left(\frac{\mu + (k \cdot \sigma)}{\mu}\right)$$

Where:
μ = The arithmetic mean of the discharges
k = The k-value or coverage factor
σ = The standard deviation of the discharges
HF = The headroom factor

Table 8: Coverage Factors and Corresponding Confidence Intervals

Coverage Factor/k-value	Confidence Interval
1.282	90.00%
1.645	95.00%
1.96	97.50%
2.326	99.00%
2.576	99.50%
3.09	99.90%

These calculations resulted in the following headroom factors, detailed in Table 9.

Table 9: Headroom Factors calculated for the generic SMR-300

Radionuclide Group	Headroom Factor (gaseous)	Headroom Factor (aqueous)
Tritium	2.09	1.89
Carbon-14	1.98	2.02
Noble Gases	3.91	N/A
Caesium-137	N/A	2.66
Iodine-131	3.89	N/A
Other Beta/Gamma emitting RNs	2.92	2.89

[10] As I-131 is used as a 'proxy' or representative RN for all halogens discharged by the generic SMR-300, the OPEX used to calculate the headroom factor was from all recorded halogens rather than from I-131 alone – this builds in additional conservatism to account for the uncertainty of not monitoring all halogens. A future evidence has been identified to create an I-131 specific HF at the site-specific stage (see QEDL_07 in Table 20).

2.8 PROSPECTIVE EFFLUENT DISCHARGES

2.8.1 Overview

The RP is required to provide estimates for annual and monthly discharges of significant aqueous and gaseous RNs to the environment [11].

As discussed earlier, estimates for annual discharges have been conducted in Estimate of the SMR-300 Gaseous and Liquid Effluent Releases using the GALE-PWR 3.2 Code [73], following the methodology described in Methodology for Calculating Liquid and Gaseous Discharges to Determine Monthly and Annual Limits [9]. The significant RNs (as determined by the methodology in Section 2.6.5) and their annual and monthly discharges are listed below, in GBq/yr.

2.8.2 Annual Discharges

2.8.2.1 Gaseous Discharges

The estimated annual total discharge of significant gaseous RNs (as determined in Section 2.6.5) are given in Table 10.

Table 10: Estimated Annual Gaseous Discharges of Radionuclides from the Generic SMR-300

Nuclide	Estimated Gaseous Effluent (GBq/yr)
Tritium	1.04E+04
Carbon-14	1.27E+02
Noble Gases	7.82E+03
Iodine-131	5.55E-04
Other beta-emitting Radionuclides associated with particulate matter	1.06E-01

Alpha activity is not considered for discharges or limits, as historical measurements carried out at PWR units confirm that discharges are below detection levels and has not been presented as a significant group of RNs. Only an accident scenario would result in any release of alpha-emitting RNs to the environment; therefore, it is out of scope for this chapter and discounted for discharge estimations and limit setting for normal operations.

2.8.2.2 Aqueous Discharges

The estimated annual total discharges of significant aqueous RNs are given in Table 11.

Table 11: Estimated Annual Aqueous Discharges of Radionuclides from the Generic SMR-300

Nuclide	Estimated Aqueous Effluent (GBq/yr)
Tritium	4.81E+03
Carbon-14	1.41E+01
Caesium-137	7.73E-02
Other beta/gamma emitting radionuclides	2.23E-01

2.8.3 Monthly Discharges

A discharge release schedule has not yet been confirmed for the generic SMR-300 design, so it is not possible to make accurate estimations of monthly discharges, as these discharges can vary greatly on a month-by-month basis.

Nevertheless, considering the design objective that the generic SMR-300 operates with an overall capacity factor of > 0.95 [2], and due to the lack of a release schedule, it has been necessary to assume that the plant can be operated with minimal variation in routine discharges to the environment during power operations. This is acceptable at Step 2 on the basis that aqueous and gaseous effluents are planned to be stored prior to scheduled release (see Liquid and Gaseous Discharge Report [10] for system design parameters) and that gaseous discharges are predicted to be relatively uniform, aside from during shutdown (when the reactor coolant is degasified), which will be considered a bounding case for gaseous discharge once the reactor has been degasified. Once source terms are available for different operational stages, the discharge releases will be calculated more accurately for each stage (See C_QEDL_100).

Section 2.8.3.1 and 2.8.3.2 assume a uniform discharge across the year for effluent RNs; the monthly discharges are calculated by dividing the annual discharges by 12. However, a conservative case for aqueous discharges would be that the maximum monthly discharge is equivalent to the maximum annual discharge; this is based on a release schedule of once per year. The former case (annual discharges divided by 12) was selected for presentation, as it was decided that this was the more realistic estimation of monthly discharges. Once discharge schedules are known, these estimations can be made more accurately (see C_QEDL_100).

2.8.3.1 Gaseous Discharges

The estimated monthly total discharge of significant gaseous RNs are given in Table 12.

Table 12: Estimated Monthly Gaseous Discharges of Radionuclides from the Generic SMR-300

Nuclide	Estimated Gaseous Effluent (GBq/month)
Tritium	8.63E+02
Carbon-14	1.05E+01
Noble Gases	6.52E+02
Iodine-131	1.85E-04
Other beta-emitting Radionuclides associated with particulate matter	8.83E-03

2.8.3.2 Aqueous Discharges

The estimated monthly total discharges of significant aqueous RNs are given in Table 13.

Table 13: Estimated Monthly Aqueous Discharges of Radionuclides from the Generic SMR-300

Nuclide	Estimated Aqueous Effluent (GBq/month)
Tritium	4.01E+02
Carbon-14	1.17E+00
Caesium-137	6.44E-03
Other beta/gamma emitting radionuclides	1.86E-02

2.9 PROPOSED DISCHARGE LIMITS

2.9.1 Overview

In order to apply for an RSR permit, a new nuclear power station must provide proposals of annual site limits for effluent discharges following the demonstration that BAT has been applied to the discharge systems and ensure minimisation of exposures to the environment and MoP, and in line with statutory limits. A full BAT demonstration will be undertaken once the design is finalised and at site specific stage to justify the proposed limits for permit application.

This section will detail the discharge limits estimated for the generic SMR-300 at GDA. These limits are calculated using the methodology outlined in Section 2.7, applying a headroom factor as a multiplier to the predicted annual discharges.

2.9.2 Gaseous Discharge Limits

Predicted gaseous discharges from the generic SMR-300 at the annual limits proposed are presented in Table 14.

Table 14: Predicted Discharges of Gaseous Radionuclides at Annual Limits

Radionuclide	Predicted Annual Discharge (GBq/yr)	Headroom Factor (2 d.p.)	Discharge at Annual Limits (GBq/yr)
Tritium	1.04E+04	2.09	2.17E+04
Carbon-14	1.27E+02	1.98	2.52E+02
Noble Gases	7.82E+03	3.91	3.06E+04
Iodine-131	5.55E-04	3.89	2.16E-03
Other beta-emitting Radionuclides associated with particulate matter	1.06E-01	2.92	3.10E-01

2.9.3 Aqueous Discharge Limits

Predicted aqueous discharges from the generic SMR-300 at the annual limits proposed are presented in Table 15.

Table 15: Predicted Discharges of Aqueous Radionuclides at Annual Limits

Nuclide	Estimated Aqueous Effluent (GBq/yr)	Headroom Factor (2 d.p.)	Discharge at Annual Limits (GBq/yr)
Tritium	4.81E+03	1.89	9.10E+03
Carbon-14	1.41E+01	2.02	2.85E+01
Caesium-137	7.73E-02	2.66	2.05E-01
Other beta/gamma emitting radionuclides	2.23E-01	2.89	6.44E-01

2.10 COMPARISON WITH SIMILAR PLANTS

2.10.1 Overview

The GDA guidance states that the Requesting Party must demonstrate that discharges and waste arisings will not exceed those of comparable power stations across the world [11]. To meet this requirement, the estimated effluent discharges from the generic SMR-300 have been compared to predicted discharges from other PWR designs submitted for GDA. Previous GDA reactor designs have provided evidence of meeting this requirement and therefore represent a useful source for comparison. This dataset also includes the predicted discharges from the FSAR for the NuScale SMR; FSARs, produced as part of the US regulatory approach, are similar in documentation to GDA PERs. Comparisons of predicted discharges to previous GDAs and FSARs are given in Section 2.10.2.

For completeness, the predicted discharges have also been compared to OPEX from relevant PWRs in the US and Europe in Section 2.10.3. The OPEX and the selection criteria are detailed in OPEX Selected for PER Chapter 2 Quantification of Discharges and Limits [8].

As methodologies for predicting limits differ between GDAs, a comparison of proposed limits between the generic SMR-300 and other GDAs has been made, and results of this comparison are given in Section 2.10.4.

To enable a meaningful comparison between different reactors and reactor designs, all discharges were normalised by power output for comparison (in Bq/MWe). Effluent discharges vary significantly between different reactors and reactor designs, so for ease of comparison, graphs (in Sections 2.10.2, 2.10.3 and 2.10.4) have been presented on a logarithmic scale. Similarly, analysis of discharges from the generic SMR-300 are deemed to be in-line with other GDAs/FSARs if they are within one order of magnitude of the average result. When this is not the case, this has been investigated for each RN group and discussed below.

Another assumption (see Section 2.2.5) in the presentation of this information is that all Halogens, Noble Gases and Other RNs are grouped in the same or similar enough categories for all the comparative OPEX to allow for a reasonable comparison. The predicted limits and discharges from the generic SMR-300 have been grouped to allow for like-for-like comparisons.

2.10.2 Comparison of Predicted Discharges with Previous GDAs/FSARs

The OPEX report [8] collated discharge data from four GDAs, one FSAR, and the Pre-Application Consultations from Hinkley Point C (HPC) and Sizewell C (SZC). The report details the selection criteria for comparable plants and designs; for GDAs and FSARs it was considered appropriate to compare the generic SMR-300 to other PWR and SMR designs. The prospective designs analysed are as follows:

- Westinghouse AP1000 (GDA).
- Rolls-Royce SMR (GDA).
- NuScale SMR (FSAR).
- HPR1000 (GDA).
- UK EPR (GDA).
- HPC (RSR permit application).
- SZC (RSR permit application).

The predicted discharges for each key group of RNs for the generic SMR-300 and comparable GDAs/FSARs are presented in Table 16. These results are presented graphically in Figure 3 and Figure 4.

Table 16: Comparison of Predicted Discharges from the generic SMR-300 to previous GDAs/FSARs

RN/RN Group & Effluent Category		Normalised Predicted Annual Reactor Discharge (Bq/MWe)							
		Generic SMR-300	Westinghouse AP1000	Rolls-Royce SMR	NuScale SMR	HPR1000	UK EPR	HPC	SZC
Tritium	Gaseous	3.47E+10	1.60E+09	8.68E+07	4.38E+10	4.43E+09	1.84E+09	1.84E+09	1.84E+09
	Aqueous	1.60E+10	3.01E+10	1.83E+08	6.78E+10	8.81E+10	4.60E+10	4.60E+10	6.13E+10
C-14	Gaseous	4.23E+08	5.47E+08	4.26E+07	1.67E+07	1.43E+09	5.52E+08	4.29E+08	4.29E+08
	Aqueous	4.70E+07	3.00E+06	1.73E+00	2.28E+07	5.00E+07	5.83E+07	5.83E+07	5.83E+07
Cs-137	Aqueous	2.58E+05	2.05E+04	2.81E+02	6.17E+05	1.64E+04	5.80E+05	5.80E+05	5.83E+05
I-131	Gaseous	1.85E+03	1.86E+05	4.06E+04	3.95E+04	7.26E+04	1.96E+05	1.12E+05	1.23E+05
Noble Gases	Gaseous	2.68E+10	1.23E+10	2.26E+10	1.58E+10	1.22E+09	1.38E+10	1.38E+10	1.38E+10
Other Radionuclides	Gaseous[11]	3.44E+05	1.55E+04	6.91E+03	9.25E+08	7.67E+03	7.36E+04	7.36E+04	3.68E+04
	Aqueous[12]	7.27E+05	2.20E+06	9.18E+03	1.52E+06	8.49E+05	5.52E+06	5.59E+06	5.49E+06

[11] Other beta-emitting RNs associated with particulate matter

[12] Other RNs (including halogenic RNs)

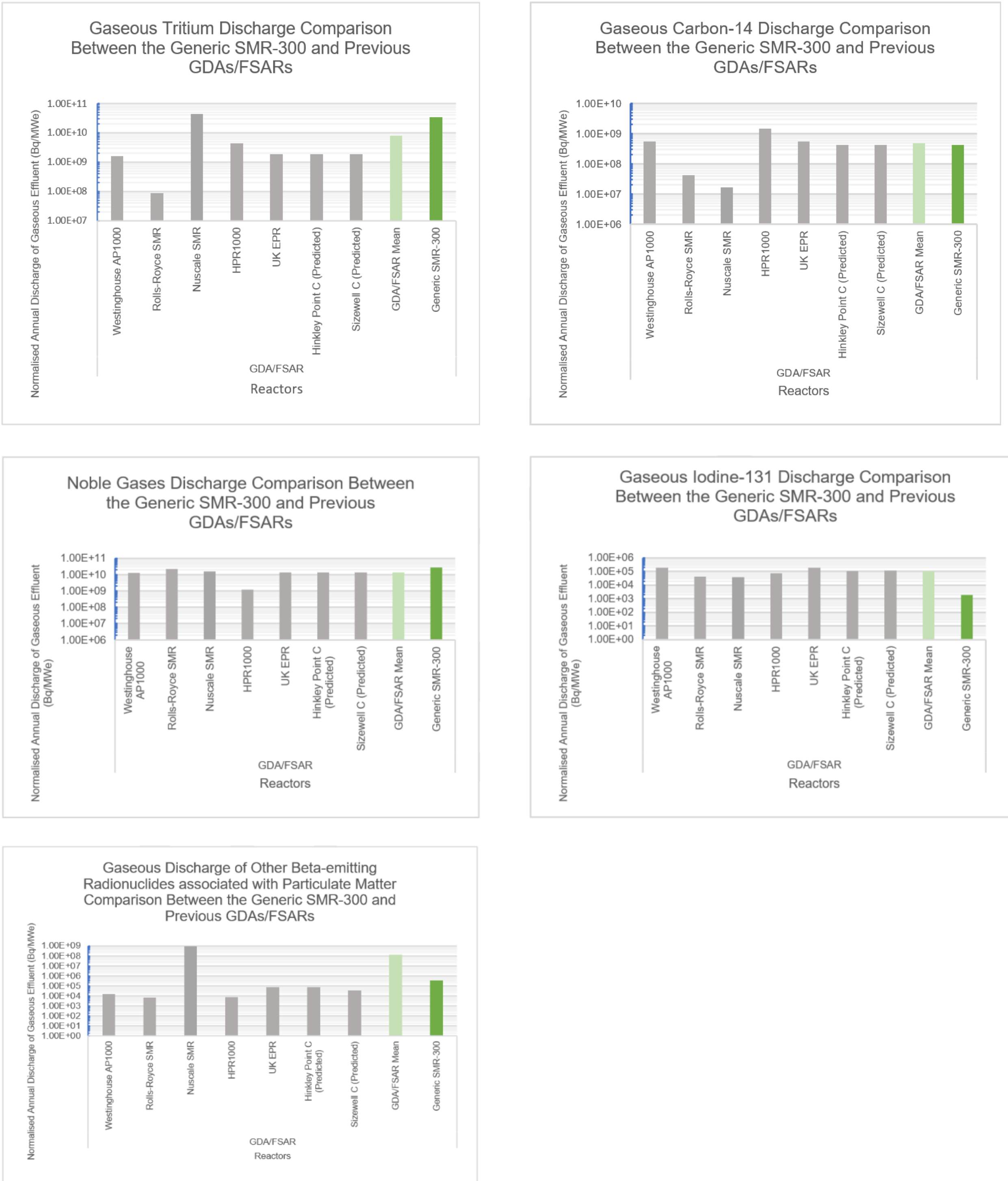

Figure 3: Graphs Comparing Normalised Annual Discharges of Gaseous Radionuclides Between the Generic SMR-300 and Previous GDAs

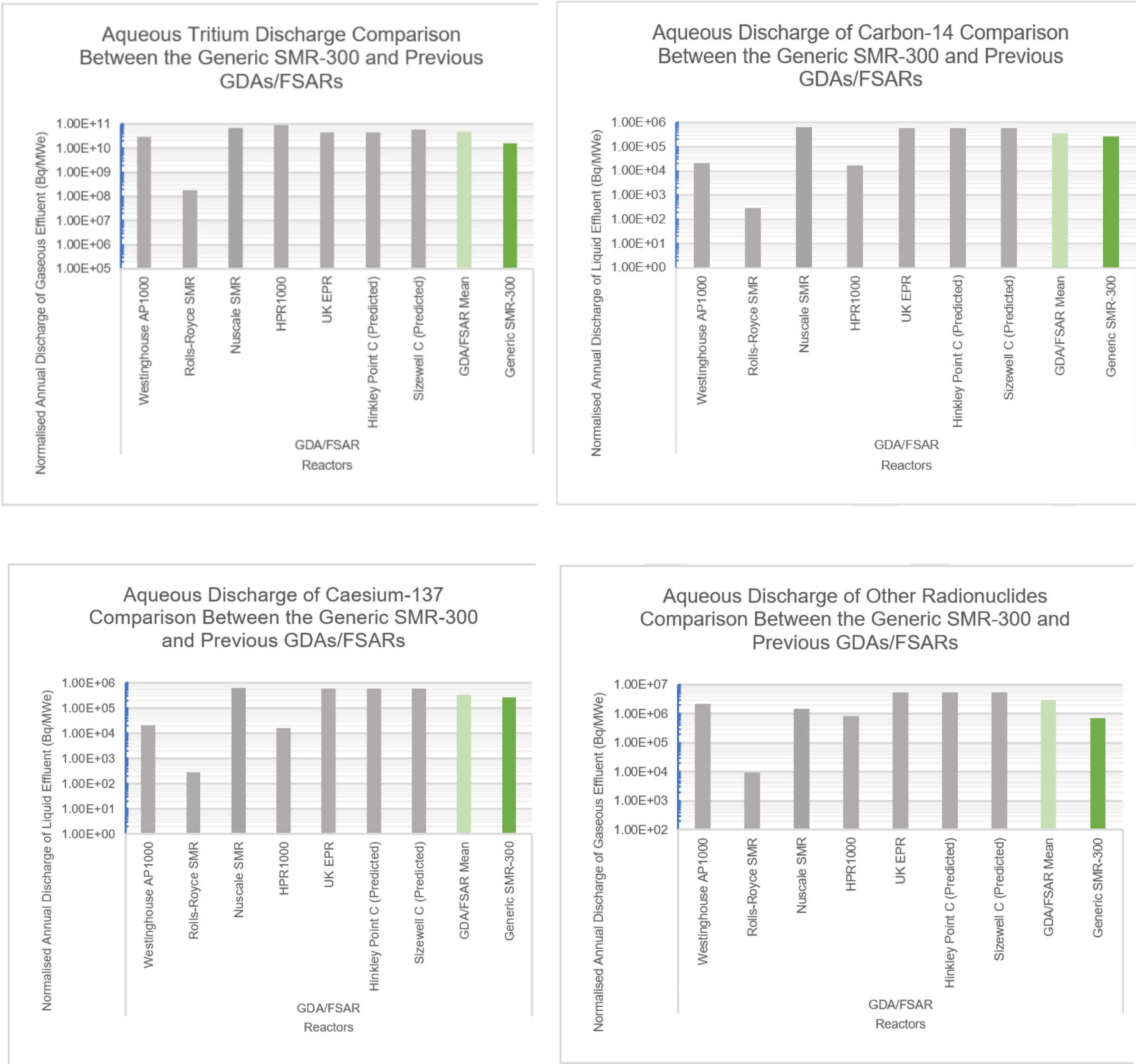

Figure 4: Graphs Comparing Normalised Annual Discharges of Aqueous Radionuclides Between the Generic SMR-300 and Previous GDAs

2.10.2.1 Conclusions

For all RNs/RN groups, the projected discharges from the generic SMR-300 are no greater than one order of magnitude larger than the mean discharge across previous GDAs/FSARs. The predicted discharges from the generic SMR-300 from the following RNs/RN groups were below the mean average from previous GDAs/FSARs:

- Gaseous: C-14, Halogens, Other RNs.
- Aqueous: H-3, Cs-137, Halogens, Other RNs.

For the following RNs/RN groups, predicted discharges from the generic SMR-300 were above the mean average from previous GDAs/FSARs[13]:

[13] The reasons for these higher discharges are discussed in Section 2.6.3.

- Gaseous: H-3, Noble Gases.
- Aqueous: C-14.

Despite the predicted discharges from the generic SMR-300 being higher than the mean average, in all cases the predicted discharge was a) less than one order of magnitude higher than the mean, and b) below the highest result from the previous GDAs/FSARs dataset. This indicates that the discharges from the generic SMR-300 are comparable to previous reactor designs, and therefore meet GDA requirements.

It is deduced that the predicted discharges from the generic SMR-300 are greater than the mean of the previous GDAs and FSAR for gaseous H-3, is that the generic SMR-300 H-3 discharge estimates are based on US OPEX, which is notably greater than that from EU plants. It is considered that this is due to differing operational approaches to tritium management, which can have a significant impact on discharges, and differing assessment methodologies between US and EU plants. This is discussed in more detail in Section 2.6.3.

It is considered that aqueous C-14 discharges of the generic SMR-300 are higher in comparison to OPEX and other GDAs/FSAR due to the partitioning factor used in calculations. The primary methodology used a partitioning factor for the gaseous to aqueous of 90:10, whereas Holtec used a partitioning factor of 80:20 in their independent validation method. It can be argued that both methods are valid, but both factors are conservative and are the theoretical highest proportions of aqueous C-14 from the two different methodologies. In an operating aqueous C-14 is likely to be present in a much lower proportion. This is described in greater detail in Methodology for Calculating Liquid and Gaseous Discharges to Determine Monthly and Annual Levels [9].

The predicted gaseous I-131 discharges from the generic SMR-300 are considerably lower than those from previous GDAs/FSARs. This is likely due to the unavailability of source terms for EEs, which would likely increase discharges of I-131 (for example, fuel pin failure would result in increased discharges of I-131). Once these source terms are available, the predicted discharge levels will be revised; see C_QEDL_100.

2.10.3 Comparison of Predicted Discharges with OPEX

The OPEX report [8] collated discharge data from 6 United States (US) PWRs and 24 EU PWRs[14], and Sizewell B (SZB) in the UK.

The US PWRs analysed are as follows:

- Watts Bar 1.
- Watts Bar 2.
- Comanche Peak 1&2.
- Seabrook 1.
- Davis-Besse.
- Oconee 1, 2&3.

[14] In the OPEX report, 7 US plants and 25 EU plants were considered. However, Vogtle 3 and Olkiluoto 3 were excluded from analysis in this chapter due to operational irregularities in the periods examined that would lead to anomalous discharge results.

The EU PWRs analysed are as follows:

- Biblis A (Germany).
- Biblis B (Germany).
- Brokdorf (Germany).
- Emsland (Germany).
- Grafenheinheld (Germany).
- Almaraz 1 & 2 (Spain).
- Belleville 1 & 2 (France).
- Blayais 1, 2, 3 & 4 (France).
- Bugey 2, 3, 4 & 5 (France).
- Cattenom 1, 2, 3 & 4 (France).
- Chinon-B 1, 2, 3 & 4 (France).
- Chooz-B 1 & 2 (France).
- Civaux 1 & 2 (France).
- Cruas 1, 2, 3 & 4 (France).
- Dampierre 1, 2, 3 & 4 (France).
- Flamanville 1 & 2 (France).
- Golfech 1 & 2 (France).
- Gravelines 1-6 (France).
- Nogent 1 & 2 (France).
- Paluel 1, 2, 3 & 4 (France).
- Penly 1 & 2 (France).
- St Alban 1 & 2 (France).
- St Laurent-B 1 & 2 (France).
- Tricastin 1, 2, 3 & 4 (France).

The only extant PWR in the UK that is relevant for comparison to the generic SMR-300 is SZB, which has also been included for analysis.

A summary of the predicted discharges for the main groups of RNs for the generic SMR-300 and comparable OPEX are presented in Table 17. The full results are presented graphically in Figure 5 – 13.

Table 17: Comparison of Predicted Discharges from the generic SMR-300 to OPEX

Radionuclide/ Group	Effluent Category	Normalised Predicted Annual Reactor Discharge (Bq/MWe)					
		Generic SMR-300	EU OPEX average	EU OPEX maximum	US OPEX average	US OPEX maximum	SZB
Tritium	Gaseous	[REDACTED]	4.47E+08	2.31E+09	1.78E+09	3.36E+09	4.88E+08
	Aqueous		1.47E+10	2.08E+10	5.42E+10	1.25E+11	1.81E+10
Carbon-14	Gaseous		1.74E+08	4.41E+08	3.24E+08	3.57E+08	2.26E+08
	Aqueous		9.43E+06	1.45E+07	N/A[15]	N/A	2.29E+06
Caesium-137	Aqueous		3.52E+04	3.36E+05	1.35E+03	3.49E+03	3.06E+05

[15] No US PWR reported any discharge of Carbon-14 in the years analysed.

Radionuclide/ Group	Effluent Category	Normalised Predicted Annual Reactor Discharge (Bq/MWe)					
		Generic SMR-300	EU OPEX average	EU OPEX maximum	US OPEX average	US OPEX maximum	SZB
Iodine-131	Gaseous		4.99E+03	1.17E+04	8.67E+04	4.29E+05	1.17E+04
Noble Gases	Gaseous		5.16E+08	7.52E+08	3.66E+09	1.69E+10	4.54E+09
Other Radionuclides	Gaseous[16]		1.44E+03	3.62E+03	9.96E+06	5.97E+07	3.43E+03
	Aqueous[17]		3.99E+05	4.88E+06	3.60E+05	6.92E+05	8.39E+05

[REDACTED]

Figure 5: Graph Comparing Normalised Annual Gaseous Tritium Discharges Between the Generic SMR-300 and OPEX

[REDACTED]

Figure 6: Graph Comparing Normalised Annual Gaseous Carbon-14 Discharges Between the Generic SMR-300 and OPEX

[REDACTED]

Figure 7: Graph Comparing Normalised Annual Noble Gases Discharges Between the Generic SMR-300 and OPEX

[16] Other beta-emitting RNs associated with particulate matter.

[17] Other RNs (including halogenic RNs).

[REDACTED]

Figure 8: Graph Comparing Normalised Annual Gaseous Iodine-131 Discharges Between the Generic SMR-300 and OPEX

[REDACTED]

Figure 9: Graph Comparing Normalised Annual Gaseous Discharges of Other Radionuclides Between the Generic SMR-300 and OPEX

[REDACTED]

Figure 10: Graph Comparing Normalised Annual Aqueous Tritium Discharges Between the Generic SMR-300 and OPEX

[REDACTED]

Figure 11: Graph Comparing Normalised Annual Aqueous Carbon-14 Discharges Between the Generic SMR-300 and OPEX

[REDACTED]

Figure 12: Graph Comparing Normalised Annual Aqueous Caesium-137 Discharges Between the Generic SMR-300 and OPEX

[REDACTED]

Figure 13: Graph Comparing Normalised Annual Aqueous Discharges of Other Radionuclides Between the Generic SMR-300 and OPEX

2.10.3.1 Conclusions

[REDACTED] It is expected that predicted discharges from new reactor designs can be higher than discharges from currently operating nuclear plants, as predictions have built-in conservatism in order to account for EEs and to set realistic discharge expectations. Therefore, while the predicted discharges for the generic SMR-300 design are higher than the OPEX averages for the majority of RNs/RN groups, the closeness of results in terms of order of magnitudes indicates that the design is in-line with comparable existing plants.

[REDACTED] As discussed in Section 2.6.3.1, tritium levels are difficult to quantify, and very dependent on tritium operational management philosophy (See section 2.6.3.1). Gaseous H-3 predictions from the generic SMR-300 are largely in-line with predicted discharges from previous GDAs/FSARs (see Section 2.10.2).

Tritium estimates will be reconsidered in future iterations of the design assessment (see C_QEDL_101) to ensure the estimates are consistent with the planned application of BAT.

2.10.4 Comparison of Proposed Limits with Previous GDAs

As stated above, different GDAs have different methodologies for generating proposed limits to effluent discharges. Therefore, a comparison of limits between the generic SMR-300 to previous GDAs has been completed, with the results presented in Table 18. Only designs that have completed the UK GDA process have proposed comparable limits, so the NuScale SMR has been excluded from this analysis. These results are presented graphically in Figure 14 and Figure 15.

Table 18: Comparison of Proposed Limits from the generic SMR-300 to previous GDAs

RN/Group & Effluent Category		Normalised Annual Discharge Limit of Effluent (Bq/MWe)						
		Generic SMR-300	Westinghouse AP1000	Rolls-Royce SMR	HPR1000	UK EPR	HPC (predicted)	SZC (predicted)
Tritium	Gaseous	[REDACTED]	2.70E+09	2.19E+08	4.43E+09	1.84E+09	1.84E+09	1.84E+09
	Aqueous		5.41E+10	1.15E+09	8.81E+10	4.60E+10	4.60E+10	6.13E+10
C-14	Gaseous		9.01E+08	7.00E+07	1.43E+09	4.29E+08	4.29E+08	4.29E+08
	Aqueous		6.31E+06	2.79E+00	5.00E+07	5.83E+07	5.83E+07	5.83E+07
Cs-137	Aqueous		4.5E+04	8.51E+02	N/A	N/A	5.80E+05	5.83E+05
I-131	Gaseous		2.70E+05	1.23E+05	1.87E+05 [18]	2.45E+05 [19]	1.12E+05	1.23E+05
Noble Gases	Gaseous		9.91E+09	8.81E+10	1.32E+05	1.38E+10	9.11E+10	1.10E+10
Other RNs	Gaseous[20]		6.94E+03	3.80E+03	9.49E+03	7.36E+04	5.64E+04	2.82E+04
	Aqueous[21]		1.26E+06	2.25E+00	8.81E+05	6.17E+06	3.11E+06	3.89E+04

[18] The HPR1000 GDA proposed a limit for the iodine group, rather than I-131 individually.

[19] The UK EPR GDA proposed a limit for the iodine group, rather than I-131 individually.

[20] Other beta-emitting RNs associated with particulate matter.

[21] Other RNs (including halogenic RNs).

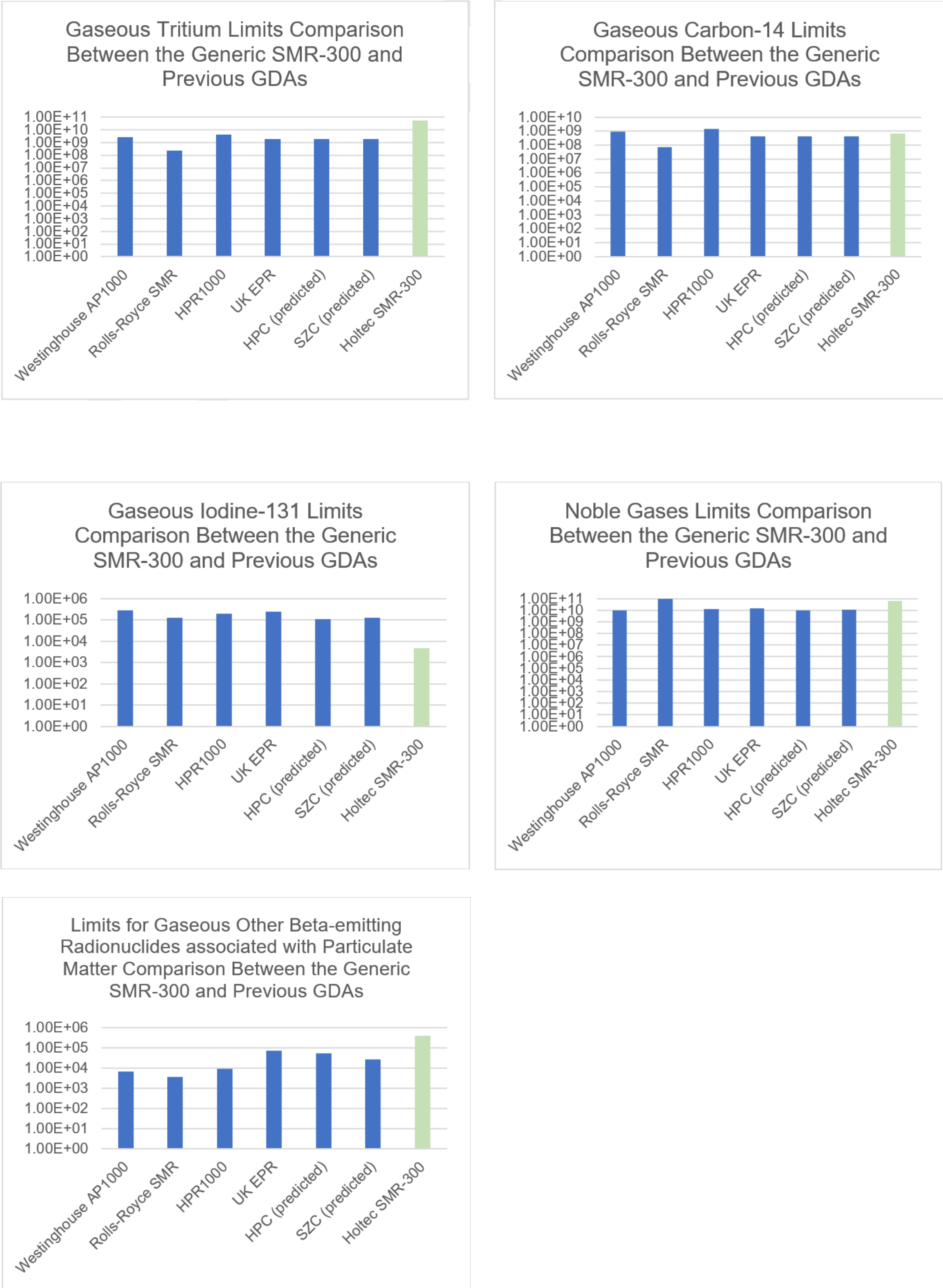

Figure 14 - Graphs Comparing Normalised Annual Limits of Gaseous Radionuclides Between the Generic SMR-300 and Previous GDAs

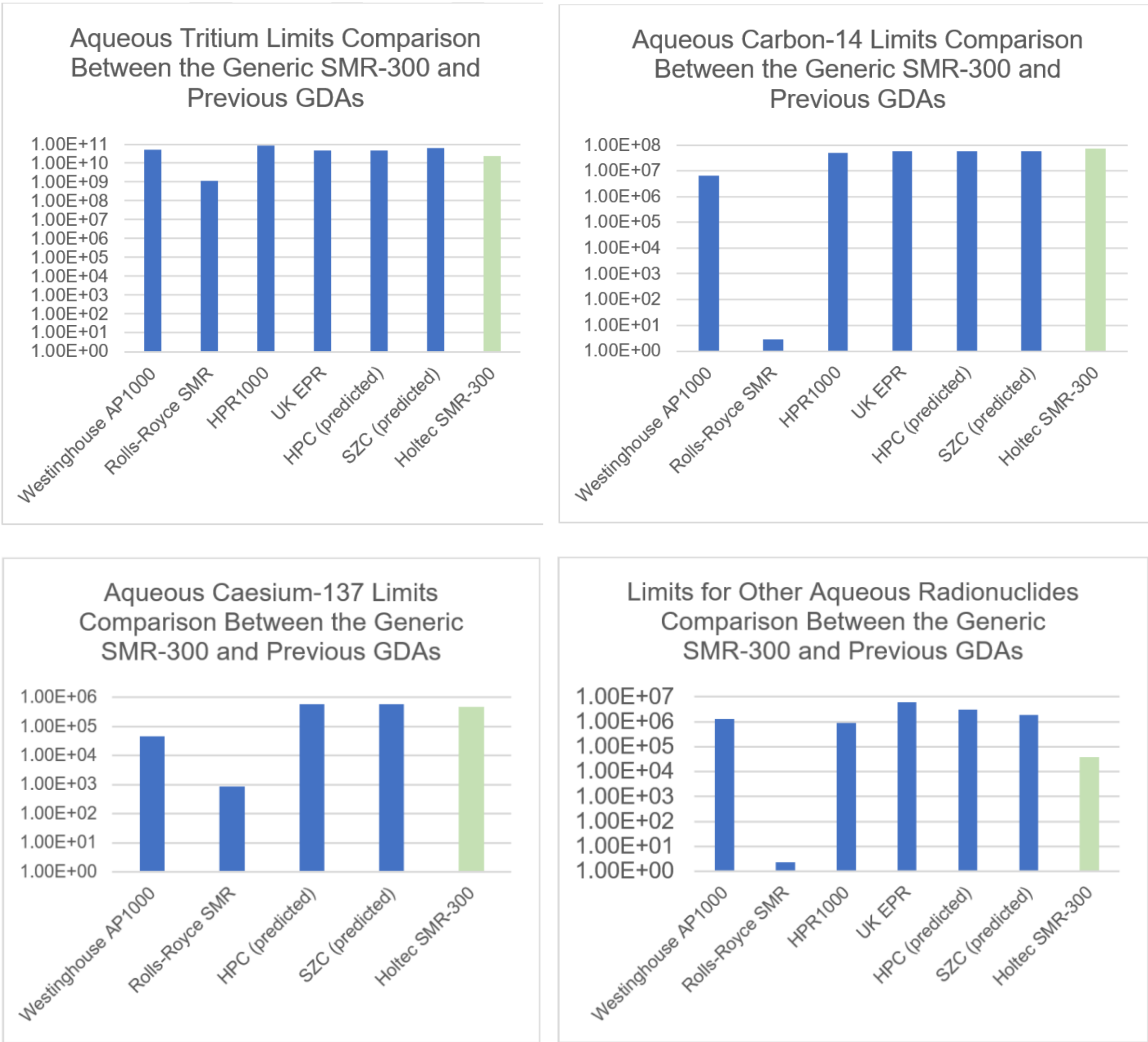

Figure 15 - Graphs Comparing Normalised Annual Limits of Aqueous Radionuclides Between the Generic SMR-300 and Previous GDAs

2.10.4.1 Conclusions

For all RNs/RN groups, with the exception of gaseous H-3 and gaseous other RNs, the proposed discharge limits from the generic SMR-300 are no greater than one order of magnitude larger than the mean discharge limits from previous GDAs.

Different GDAs have used different methodologies to calculate headroom factors/limits, so it is expected that there will be some variation in proposed limits between designs. The similarity in magnitude of limits for the majority of RNs indicates that discharges from the generic SMR-300 are comparable to similar reactor designs.

[REDACTED]

Additionally, there is potential for these limits to be revised at a later stage in development of the reactor site. Commitment C_QEDL_101 addresses the intention to revise the H-3 discharge estimates in future stages of design, which will in turn revise the proposed limit.

[REDACTED] Again, this limit may be revised at a later stage in development of the reactor site.

The normalised proposed limit for gaseous I-131 is considerably lower than the limits proposed in previous GDAs. As discussed in Section 2.10.2.1, this is likely due to the lack of specific source terms for EEs for the generic SMR-300, and this limit will be reassessed when these source terms are available; see C_QEDL_100.

2.11 SUMMARY

This chapter has presented the methodologies and philosophies that have been used to assess aqueous and gaseous radioactive discharges from the generic SMR-300 design. It has outlined the development of the normal operations source term and explained how this source term has been used to derive estimates of effluent discharges resulting from normal operations on an annual and monthly basis. The significant RNs are grouped in line with other permit and GDA/FSAR groupings to enable estimation of discharges and comparison. The discharge estimates have then been compared to previous GDAs/FSARs and OPEX from relevant PWRs, to demonstrate that discharges from the generic SMR-300 are not too dissimilar. It is also recognised that methodologies for monitoring and measurement may not be the same from all reactors used in the OPEX, and groupings of radionuclides could differ. Therefore, best endeavours have been used in providing the comparisons and explanations have been detailed in the methodologies used for the generic SMR-300.

Discharge estimates from significant RNs in this chapter will be used to inform the RIA and future impact assessments. Initial calculations from the RIA have identified that C-14 and H-3 discharges were the predominant contributors (>98%) of dose to MoP.

This chapter has also described the methodology for calculating headroom factors for the individual and grouped RNs and subsequent limits.

2.12 GDA COMMITMENTS AND FUTURE EVIDENCE

Beyond GDA timescales the management of the quantification of effluent discharges and limits will continue to develop in line with the evolving maturity of the generic SMR-300 design, as well as the requirements of site-specific permitting.

Commitments for future stages of regulatory engagement are shown in Table 19 and recorded in the Commitments, Assumptions, Requirements Register [83]. Commitments will form part of any hand-over package post GDA:

Table 19: GDA Commitments

Chapter Section	Reference	Description of Commitment	Target for Resolution
2.4.4	C_QEDL_100:	Currently the estimates of discharges for the SMR-300 do not reflect the variation in discharges that can take place over the course of the fuel cycle or adequately factor in contributions from unplanned but not unexpected events. A commitment is raised to undertake a detailed assessment of estimated discharge source terms (on an annual and monthly basis) once discharge schedules and process-specific source terms are available, to ensure proposed limits account for the following aspects of normal operation: Start-up and shutdown. Maintenance and testing. Infrequent but necessary aspects of operation, for example, plant wash-out. Load following power operation. Expected events.	Issue of UK Pre-Construction SSEC
2.6.3	C_QEDL_101:	The current methods for determining discharges associated with Tritium and Argon-41 are overly conservative due to uncertainty relating to design information available for a 2-Step GDA. A Commitment is raised to ensure revised methodologies for calculating discharges of Argon-41 and Tritium are developed once the design has matured to a level at which reactor-specific values can be used to remove conservative assumptions..	Issue of Pre-Construction SSEC.

Further work to be undertaken as part of normal business where a GDA commitment was not required, is incorporated into an indicative list of future evidence (see Table 20).

Table 20: Future Evidence

[REDACTED]

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