Office for Nuclear Regulation

ONR Assessment Report

Generic Design Assessment of the BWRX-300 – Step 2 Assessment of Radiological Protection

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Project Name: Generic Design Assessment of the BWRX-300 – Step 2

Report Title: Step 2 Assessment of Radiological Protection

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Executive summary

In December 2024, the Office for Nuclear Regulation (ONR), together with the Environment Agency and Natural Resources Wales, began Step 2 of the Generic Design Assessment (GDA) of the BWRX-300 design on behalf of GE Vernova Hitachi Nuclear Energy International LLC, United Kingdom (UK) Branch, the Requesting Party (RP).

This report presents the outcomes of my radiological protection assessment of the BWRX-300 design as part of Step 2 of the ONR GDA. This assessment is based upon the information presented in the RP's safety, security, safeguards, and environment cases (SSSE), the associated revision 2 of the Design Reference Report and supporting documentation.

ONR's GDA process calls for an assessment of the RP's submissions, which increases in detail as the project progresses. The focus of my assessment in this step was to support ONR's decision on the fundamental adequacy of the BWRX-300 design and safety case, and the suitability of the methodologies, approaches, codes, standards and philosophies which form the building blocks for the design and generic safety, security and safeguards cases.

I targeted my assessment, in accordance with my assessment plan, at the areas that were fundamental to the acceptability of the design and methods for deployment in Great Britain (GB), benchmarking my regulatory judgements against the expectations of the ONR's Safety Assessment Principles (SAPs), Technical Assessment Guides (TAGs) and other guidance which ONR regards as relevant good practice (RGP), such as the International Atomic Energy Agency (IAEA) safety, security and safeguards standards. Where appropriate, I have also considered how I could use relevant learning and regulatory conclusions from the UK ABWR GDA to inform my assessment of the BWRX-300.

I targeted the following aspects in my assessment of the BWRX-300 SSSE:

- The adequacy of the overall radiological protection aspects of the SSSE cases, focussing at this stage on the adequacy of the claims and arguments.
- Whether the BWRX-300 conceptual design is capable of enabling a future dutyholder to comply with requirements of the Ionising Radiations Regulations 2017 (IRR17).
- The RP's approach to ensuring exposures to workers and direct radiation doses to any persons off the site could be As Low As is Reasonably Practicable (ALARP) during normal operations.
- The radiological source terms for normal operation, so as to gain confidence they are sufficiently characterised, consider relevant Operational Experience (OPEX) and that radioactivity within the design is likely to be reduced to ALARP.

- The approach to implement an optimised radiation shielding design.
- The approach to protect against out of core criticality.

Based upon my assessment, I have concluded the following:

- I judge the format, structure, and content of the radiological protection aspects I assessed at Step 2 to be consistent with UK regulatory expectations and IAEA guidance. The Claims, Arguments, and Evidence (CAE) are sufficient for purposes of Step 2, however, it would be beneficial to develop more specific claims for radiological protection. At Step 2, the safety case currently lacks sufficient evidence to support the safety claims and arguments in Preliminary Safety Report (PSR) Chapter 12; this will need to be addressed in a future safety case submission.
- I have not identified any fundamental shortfalls that would prevent future compliance with IRR17. I consider the BWRX-300 conceptual design to be capable of meeting IRR17 requirements in the future; this is subject to completion of further work identified in the Forward Action Plan (FAP).
- It is evident that OPEX and international guidance has been used to inform radiological protection objectives and design requirements; and that the RP has established a suitable process for assessing design changes and improvements to reduce exposures to ALARP as the design progresses.
- I judge that the approach for the dose assessment at conceptual design phase is consistent with UK and international guidance. A future safety case will need to provide sufficiently detailed dose assessments and justification that the individual doses are acceptable and reduced to ALARP.
- I judge that radiological source terms for the BWRX-300 are sufficiently developed and conservatively derived for the purposes of design development (e.g. shielding design). I consider the BWRX-300 design choices to minimise source terms to be consistent with UK and international guidance. The RP recognises the need to develop a full suite of substantiated source terms to underpin shielding analysis and dose assessments, as captured in the FAP.
- The RP has used OPEX to inform the shielding design and requirements, alongside industry recognised codes and approaches to assess shielding provisions in line with UK guidance. I judge this to be sufficient for Step 2 assessment; however, a future safety case will need to demonstrate with evidence that shielding provisions have been substantiated and where appropriate optimised as the design progresses.
- Based on the RP's use of OPEX and proposed approaches, it is my opinion that the BWRX-300 will be designed to modern standards and capable of being operated within regulatory dose limits outlined in IRR17 and below the Basic Safety Levels (BSLs) for Targets 1, 2, and 3. A future safety case will need to provide sufficiently detailed dose assessments to demonstrate

compliance with all dose limits outlined in IRR17 and further justification that doses to workers and the public have been reduced to ALARP.

- Finally, no fundamental issues with respect to out of core criticality have been identified during the Step 2. A future safety case will need to provide evidence of substantiation underpinning the criticality safety arguments.

Overall, based on my assessment to date I have not identified any fundamental safety shortfalls that could prevent ONR permissioning the construction of a power station based on the generic BWRX-300 design; noting that any decision to permission a BWRX-300 will require further assessment (in either a future Step 3 GDA or during site specific activities) of suitable and sufficient supporting evidence that can substantiate the claims and proposals made in the Step 2 submissions.

List of abbreviations

ACoP	Approved Code of Practice
ALARA	As low as is reasonably achievable
ALARP	As low as is reasonably practicable
AO	ALARA Objective
AOOs	Anticipated Operation Occurrences
ABWR	Advanced Boiler Water Reactor
BSL	Basic Safety Level
BSO	Basic Safety Objective
BWR	Boiling Water Reactor
CAE	Claim, Argument and Evidence
CNSC	Canadian Nuclear Safety Commission
DAC	Design Acceptance Confirmation
DB	Design Basis
DRR	Design Reference Report
ESBWR	Economic Simplified Boiling Water Reactor
FAP	Forward Action Plan
GB	Great Britain
GDA	Generic Design Assessment
GVHA	GE Vernova Hitachi Nuclear Energy Americas LLC
HFE	Human Factors Engineering
HWC	Hydrogen Water Chemistry
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
IGSCC	Inter-Granular Stress Corrosion Cracking
IRR17	Ionising Radiations Regulations 2017
NRC	Nuclear Regulatory Commission
OLNCTM	On-Line NobleChem™
ONR	Office for Nuclear Regulation
OPEX	Operational Experience
PA	Protected Areas
PER	Preliminary Environment Report
PrST	Process Source Terms
PSAR	Preliminary Safety Analysis Report
PSR	Preliminary Safety Report
PST	Primary Source Terms
RGP	Relevant Good Practice
RAMI	Reliability, Availability, Maintainability, and Inspectability
RITE	Risk Informed, Targeted Engagements
RP	Requesting Party
RPV	Reactor Pressure Vessel
RQ	Regulatory Query
SAP	Safety Assessment Principle(s)
SBWR	Simplified Boiling Water Reactor
SSSE	Safety, Security, Safeguards and Environment Cases
SSCs	Structures, Systems and Components

SSG	Specific Safety Guide (IAEA)
SFAIRP	So far as is reasonably practicable
TAG	Technical Assessment Guide(s) (ONR)
TSC	Technical Support Contractor
UK	United Kingdom
US	United States of America
WENRA	Western European Nuclear Regulators' Association

Contents

1. Introduction

1. This report presents the outcome of my radiological protection assessment of the BWRX-300 design as part of Step 2 of the Office for Nuclear Regulation (ONR) Generic Design Assessment (GDA). My assessment is based upon the information presented in the safety, security, safeguards and environment cases (SSSE) head document (ref. [1]), specifically chapters 1, 2, 3, 9A, 12, 23, 27, (refs. [2], [3], [4], [5], [6], [7], [8]) the associated revision of the Design Reference Report (DRR) (ref. [9]) and supporting documentation.

2. Assessment was undertaken in accordance with the requirements of ONR's Management System and follows ONR's guidance on the mechanics of assessment, NS-TAST-GD-096 (ref. [10]) and ONR's risk informed, targeted engagements (RITE) guidance (ref. [11]. The ONR Safety Assessment Principles (SAPs) (ref. [12]), together with supporting Technical Assessment Guides (TAGs) (ref. [13]), have been used as the basis for this assessment.

3. This is a Major report as per ONR's guidance on the production of reports NAST-GDA-GD-108 (ref. [14]).

1.1. Background

4. The ONR's GDA process (ref. [15]) calls for an assessment of the Requesting Party's (RP) submissions with the assessments increasing in detail as the project progresses. This GDA will be finishing at Step 2 of the GDA process. For the purposes of the GDA, GE Vernova Hitachi Nuclear Energy International LLC, United Kingdom (UK) Branch, is the RP. GE Vernova Hitachi Nuclear Energy Americas LLC (GVHA) is a provider of advanced reactors and nuclear services and is the designer of the BWRX-300. GVHA is headquartered in Wilmington, North Carolina, United States of America (US).

5. In Step 1, and for the majority of Step 2, the RP was known as GE-Hitachi Nuclear Energy International LLC, UK Branch, and GVHA as GE-Hitachi Nuclear Energy Americas LLC. The entities formally changed names in October 2025 and July 2025 respectively. The majority of the submissions provided by the RP during GDA were produced prior to the name change, and thus the reference titles in Section 6 of this report reflects this.

6. In the UK, the RP has been supported by its supply chain partner, Amentum, who has assisted the RP in the development of the UK-specific chapters of the SSSE, and other technical documents for the GDA.

7. In January 2024 ONR, together with the Environment Agency and Natural Resources Wales began Step 1 of this two-Step GDA for the generic BWRX-300 design.

8. Step 1 is the preparatory part of the design assessment process and is mainly associated with initiation of the project and preparation for technical assessment in Step 2. Step 1 completed in December 2024. Step 2 is the first substantive technical assessment step, and began in December 2024 and will complete in December 2025.

9. The RP has stated that at this time it has no plans to undertake Step 3 of GDA and obtain a Design Acceptance Confirmation (DAC). It anticipates that any further assessment by the UK regulators of the BWRX-300 design will be on site-specific basis and with a future licensee.

10. The focus of ONR's assessment in Step 2 was:

- The fundamental adequacy of the design and safety, security, and safeguards cases; and
- The suitability of the methodologies, approaches, codes, standards, and philosophies which form the building blocks for the design and cases.

11. The objective is to undertake an assessment of the design against regulatory expectations to identify any fundamental safety, security or safeguards shortfalls that could prevent ONR permissioning the construction of a power station based on the design.

12. Prior to the start of Step 2 I prepared a detailed Assessment Plan for radiological protection (ref. [16]). This has formed the basis of my assessment and was also shared with the RP to maximise openness and transparency.

13. This report is one of a series of assessments which support ONR's overall judgements at the end of Step 2 which are recorded in the Step 2 Summary Report (ref. [17]) and published on the regulators' website.

1.2. Scope

14. The assessment documented in this report is based upon the SSSE for the BWRX-300 (refs. [1], [2], [3], [4], [18], [19], [20], [21], [22], [5], [23], [24], [25], [6], [26], [27], [28], [29], [30], [31], [32], [33], [34], [35], [36], [37], [38], [39], [40], [41], [42], [43], [44], [7], [45], [46], [47], [8], [48]).

15. The RP's GDA scope has been agreed between the regulators and the RP during Step 1. This is documented in an overall Scope of Generic Design Assessment report (ref. [49]). This is further supported by its DRR (ref. [9]) and the MDSL (ref. [50]). The GDA scope report documents the submissions which were provided in each topic area during Step 2 and provides a brief overview of the physical and functional scope of the Nuclear Power Plant (NPP) that is proposed for consideration in the GDA. The DRR provides a list of the systems, structures, and components (SSCs) which are included in the scope of the GDA, and their relevant GDA reference design documents.

16. The RP has stated it does not have any current plans to undertake GDA beyond Step 2. This has defined the boundaries of the GDA and therefore of my own assessment.

17. The GDA scope includes the Power Block (comprising the Reactor Building, Turbine Building, Control Building, Radwaste Building, Service Building, Reactor Auxiliary Structures) and Protected Areas (PA) as well as the balance of plant. It includes all modes of operation.

18. The regulatory conclusions from GDA apply to everything that is within the GDA scope. However, ONR does not assess everything within it, or all matters to the same level of detail. This applies equally to my own assessment, and I have followed ONR's guidance on the mechanics of assessment, NS-TAST-GD-096 (ref. [10]) and ONR's guidance on Risk Informed, Targeted Engagements (ref. [11]).

19. As appropriate for Step 2 of the GDA, information has not been submitted for all aspects within the GDA Scope during Step 2. The following aspects of the SSSE are therefore out of scope of this assessment:

- Operating procedures, instructions, practices, and activities that are under the ownership of the future dutyholder (licensee).
- Doses due to fault sequences.
- Accident and exposure management under the Radiation (Emergency Preparedness and Public Information) Regulations 2019 (ref. [51]).
- Radiography practices associated with heavy pressure vessels and mechanical, electrical, and plumbing systems.
- Radiological source terms estimation and dose rate calculations for radiation zoning for BWRX-300 (ref. [49]).
- Detailed worker dose assessment based on task analysis for the BWRX-300 (ref. [49]).

20. My assessment has considered the following aspects:

- The adequacy of the overall radiological protection aspects of the SSSE cases, focussing at this stage on the adequacy of the claims and arguments.
- Whether the BWRX-300 conceptual design is capable of enabling a future dutyholder to comply with requirements of the IRR17.
- The RP's approach to ensuring exposures to workers and direct radiation doses to any persons off the site are As Low As is Reasonably Practicable (ALARP) during normal operations.

- Confidence that radiological source terms for normal operation are sufficiently characterised, consider relevant OPEX and that radioactivity within the design is likely to be reduced SFAIRP.

- The approach to implement an optimised radiation shielding design.

- The approach to protect against out of core criticality.

2. Assessment standards and interfaces

21. The primary goal of the Step 2 assessment is to reach an independent and informed judgment on the adequacy of the RP's SSSE for the reactor technology being assessed.

22. ONR has a range of internal guidance to enable Inspectors to undertake a proportionate and consistent assessment of such cases. This section identifies the standards which have been considered in this assessment. This section also identifies the key interfaces with other technical topic areas.

2.1. Standards

23. The ONR SAPs (ref. [12]) constitute the regulatory principles against which the RP's case is judged. Consequently, the SAPs are the basis for ONR's assessment and have therefore been used for the Step 2 assessment of the BWRX-300.

24. The International Atomic Energy Agency (IAEA) safety standards (ref. [52]) and nuclear security series (ref. [53]) are a cornerstone of the global nuclear safety and security regime. They provide a framework of fundamental principles, requirements, and guidance. They are applicable, as relevant, throughout the entire lifetime of facilities and activities.

25. Furthermore, ONR is a member of the Western European Nuclear Regulators Association (WENRA). WENRA has developed Reference Levels (ref. [54]), which represent good practices for existing nuclear power plants, and Safety Objectives for new reactors (ref. [55]).

26. The relevant SAPs, IAEA standards and WENRA reference levels are embodied and expanded on in the TAGs (ref. [13]). The TAGs provide the principal means for assessing the radiological protection aspects in practice.

27. The key guidance is identified below and referenced where appropriate within Section 4 of this report. Relevant good practice (RGP), where applicable, has also been cited within the body of this report.

2.1.1. Safety Assessment Principles (SAPs)

28. The key SAPs applied within my assessment are:

29. Radiation Protection principles RP.1 to RP.7 were considered, however, the following RP principles were key to my assessment:

- **RP.1 - Normal Operation (Planned Exposure Situations):** Adequate protection against exposure to radiation and radioactive substances should be provided in those parts of the facility to which access is permitted during normal operation.

- **RP.3 - Designation of Areas:** Where appropriate, designated areas (as outlined in IRR17) should be further divided, with associated controls, to restrict exposure and prevent the spread of radioactive material.

- **RP.6 – Shielding:** Where shielding has been identified as a means of restricting dose, it should be effective under all normal operation and fault conditions where it provides this safety function.

- **RP.7 - Hierarchy of Control Measures:** The dutyholder should establish a hierarchy of control measures to optimise protection in accordance with IRR17.

30. As defined in the SAPs, normal operations include all the operating modes permitted at the facility, such as start-up and shutdown states and temporary situations arising due to maintenance and testing. They also include minor deviations from desired operating conditions provided these are appropriately justified in the safety case (they include what the IAEA terms Anticipated Operational Occurrences).

31. Numerical targets and legal limits:

- **NT.1 - Assessment against targets:** Safety cases should be assessed against the SAPs numerical targets for normal operational, design basis fault and radiological accident risks to people on and off the site.

- **Target 1 - Normal operation – any person on the site:** The targets and legal limit for effective dose in a calendar year for any person on the site from sources of ionising radiation.

- **Target 2 - Normal operation – any group on the site:** The targets for average effective dose in a calendar year to defined groups of employees working with ionising radiation.

- **Target 3 - Normal operation – any person off the site:** The target and legal limit for effective dose in a calendar year for any person off the site from sources of ionising radiation originating on the site.

32. Engineering Principles: Criticality Safety

- **ECR.1 - Safety measures:** Wherever a significant amount of fissile material may be present, there should be safety measures to protect against unplanned criticality.

- **ECR.2 - Double contingency approach:** Criticality safety cases should employ the double contingency approach. The double contingency approach involves a demonstration that unintended criticality cannot occur unless at least two unlikely, independent, concurrent changes in the conditions originally specified as essential to criticality safety have occurred.

33. A list of the SAPs used in this assessment is recorded in Appendix 1.

2.1.2. Technical Assessment Guides (TAGs)

34. The following TAGs have been used as part of this assessment:

- **NS-TAST-GD-002** Radiation Shielding (ref. [56])
- **NS-TAST-GD-005** Regulating duties to reduce risks to ALARP (ref. [57])
- **NS-TAST-GD-018** Criticality Warning Systems (ref. [58])
- **NS-TAST-GD-041** Criticality Safety (ref. [59])
- **NS-TAST-GD-043** Radiological Analysis - Normal Operation (ref. [60])
- **NS-TAST-GD-097** Criticality Safety Assessment of Transport Packages (ref. [61])

2.1.3. National and international standards and guidance

35. The following international standards and guidance have been used as part of this assessment:

- **IRR17:** The Ionising Radiations Regulations 2017 and associated Approved Code of Practice (ACoP) (ref. [62]) outlines the GB regulatory requirements.
- **SSR-2/1:** IAEA, Safety of Nuclear Power Plants: Design, IAEA Specific Safety Requirements No. SSR-2/1, 2016 (ref. [63]). This publication establishes design requirements for the SSCs of a nuclear power plant, including radiation protection in design (requirements 5 and 81).
- **SSG-61:** IAEA, Format and Content of the Safety Analysis Report for Nuclear Power Plants, Specific Safety Guide No. SSG-61, 2021 (ref. [64]). This guide provides recommendations on the structure and content of the safety analysis report submitted by the operating organisation in support of an application to the regulatory body for authorisation of the siting, construction, commissioning, operation, and decommissioning of a nuclear power plant.
- **SSG-63:** IAEA, Design of Fuel Handling and Storage Systems for Nuclear Power Plants, Specific Safety Guide No. SSG-63, 2020 (ref. [65]). The guide provides recommendations for the design of fuel handling and storage systems in nuclear power plants, including criticality safety.
- **SSG-90:** IAEA, Radiation Protection Aspects of Design for Nuclear Power Plants, Specific Safety Guide No. SSG-90, 2024 (ref. [66]). This

guide provides recommendations for ensuring radiation protection in the design of new nuclear power plants.

36. It should be noted that ONR guidance uses the term ‘as low as reasonably practicable’ (ALARP) as a convenient means to express the legal duty to reduce risks so far as reasonably practicable (SFAIRP). For assessment purposes the terms ALARP and SFAIRP are interchangeable and require the same tests to be applied. ALARP is also equivalent to the phrase ‘as low as reasonably achievable’ (ALARA) used in relation to ionising radiation exposure by other national and international bodies.

2.2. Integration with other assessment topics

37. To deliver the assessment scope described above I have worked closely with a number of other topics (including the Environment Agencies) to inform my assessment. Similarly, other assessors sought input from my assessment. These interactions are key to the success of GDA to prevent or mitigate any gaps, duplications, or inconsistencies in ONR’s assessment.

38. The key interactions with other topic areas were:

- **Chemistry** led on the adequacy and justification of the normal operation source terms. Radiological protection has considered whether the source terms are sufficiently characterised, optimised, and bounding for the purposes of the radiological protection claims and arguments.
- **Environment Agencies** have led on assessing all dose pathways to members of the public during normal operation. I have interacted with the Environment Agency on radiation exposures to members of the public from direct radiation shine.
- Other topic areas were also consulted during the assessment, including **Nuclear Liabilities Regulation**, **Mechanical Engineering & Structural Integrity**, and **Fuel and Core & Fault Studies**.

2.3. Use of technical support contractors

During Step 2 I have not engaged Technical Support Contractors (TSCs) to support my assessment of the radiological protection aspects of the BWRX-300 GDA.

3. Requesting Party's submission

39. The RP submitted the SSSE at the start of Step 2 in four volumes that integrate environmental protection, safety, security, and safeguards. This was accompanied by a head document (ref. [1]), which presents the integrated GDA environmental, safety, security, and safeguards case for the BWRX-300 design.

40. All four volumes were subsequently consolidated to incorporate any commitments and clarifications identified in regulatory engagements, regulatory queries, and regulatory observations, and were resubmitted in July 2025. This consolidated revision is the basis of the regulatory judgements reached in Step 2.

41. This section presents a summary of the RP's safety case for radiological protection. It also identifies the documents submitted by the RP which have formed the basis of my Step 2 assessment of the BWRX-300 design.

3.1. Summary of the BWRX-300 Design

42. The BWRX-300 is a single unit, direct-cycle, natural circulation, boiling water reactor with a power of ~870 MW (thermal) and a generating capacity of ~ 300 MW (electrical) and is designed to have an operational life of 60 years. The RP claims the design is at an advanced concept stage of development and is being further developed during the GDA in parallel with the RP's SSSE.

43. The BWRX-300 is the tenth generation of the boiling water reactor (BWR) designed by GVHA and its predecessor organisations. The BWRX-300 design builds upon technology and methodologies used in its earlier designs, including the Advanced Boiling Water Reactor (ABWR), Simplified Boiling Water Reactor (SBWR) and the Economic Simplified Boiling Water Reactor (ESBWR). The ABWR has been licensed, constructed and is currently in operation in Japan, and a UK version of the design was assessed in a previous GDA with a view to potential deployment at the Wylfa Newydd site. Neither the SBWR or ESBWR have been built or operated.

44. The BWRX-300 reactor core houses 240 fuel assemblies and 57 control rods inside a steel reactor pressure vessel (RPV). It uses fuel assemblies (GNF2) that are already currently widely used globally (ref. [6]).

45. The reactor is equipped with several supporting systems for normal operations and a range of safety measures are present in the design to provide cooling, control criticality and contain radioactivity under fault conditions. The BWRX-300 utilises natural circulation and passive cooling rather than active components, reflecting the RP's design philosophy.

3.2. BWRX-300 Case Approach and Structure

46. The RP has submitted information on its strategy and intentions regarding the development of the SSSE (refs [67], [68], [69], [70]). This was submitted to ONR during Step 1.

47. The RP has submitted a SSSE for the BWRX-300 that claims to demonstrate that the standard BWRX-300 can be constructed, operated, and decommissioned on a generic site in Great Britian (GB) such that a future licensee will be able to fulfil its legal duties for activities to be safe, secure and will protect people and the environment. The SSSE comprises a Preliminary Safety Report (PSR) which also includes information on its approach to safeguards and security, a security assessment, a Preliminary Environment Report (PER), and their supporting documents.

48. The format and structure of the PSR largely aligns with the IAEA guidance for safety cases, SSG-61 (ref. [64]), supplemented to include UK specific chapters such as Structural Integrity and Chemistry. The RP has also provided a chapter on ALARP, which is applicable to all safety chapters. The RP has stated that the design and analysis referenced in the PSR is consistent with the March 2024 Preliminary Safety Analysis Report (PSAR) submitted to the US Nuclear Regulatory Commission (NRC). The Security Assessment and PER are for the same March 2024 design but have more limited links to any US or Canadian submissions.

3.3. Summary of the RP’s case for Radiological Protection

49. The aspects covered by the BWRX-300 SSSE case in the area of radiological protection (or radiation protection) can be broadly grouped under four headings which are summarised as follows:

3.3.1. PSR Chapter 12 Radiation Protection

50. The radiological protection of workers is summarised in PSR Chapter 12 (ref. [6]). The intended purpose is to demonstrate that the design and operation of the BWRX-300 will ensure that the radiation doses to workers are reduced to ALARP. The chapter provides information on the strategy, methods, and provisions for radiation protection. The expected occupational exposures during operational states, and the measures taken to avoid and restrict exposures.

51. Appendix A of PSR Chapter 12 presents the claims, arguments, and evidence. The highest level 2 claim is that “**2.1 The functions of systems and structures have been derived and substantiated taking into account RGP and OPEX, and processes are in place to maintain these through-life**.” This claim is broken down into the following level 3 chapter claims and arguments:

- **Claim 2.1.2:** The design of the system/structure has been substantiated to achieve the safety functions in all relevant operating modes.
    - **Argument**: Source terms for dose assessments have been shown to be sufficiently developed and conservative. Shielding design source terms are used to demonstrate the requirements of radiation zones are maintained during all modes of operation. Dose assessments for the key activities during operation and outages are used to ensure the occupational doses are below legal limits.
- **Claim 2.1.3:** The system/structure design has been undertaken in accordance with relevant design codes and standards (RGP) and design safety principles, and taking account of Operating Experience to support reducing risks to ALARP.
    - **Argument**: The ALARP principles focused on the risk of radiation exposure are consistently applied during the design of equipment and facility, integrating RGP and OPEX. Design criteria consistent with U.S. regulatory guidance have been established to meet ALARP objectives in line with international standards.

52. The above claims and arguments are supported by information provided in PSR Chapter 12 as well as supporting reference documents.

3.3.2. PSR Chapter 23 Reactor Chemistry

53. PSR Chapter 23 (ref. [7]) describes the reactor chemistry (including radioactive source terms) which is relevant to my assessment of radiological protection. The main claim in PSR Chapter 23 relevant to my assessment is "**2.4 Safety risks have been reduced as low as reasonably practicable**." This claim is broken down into the following level 3 chapter claim and argument:

- **Claim 2.4.1:** RGP has been taken into account across all disciplines.
    - **Argument** d) The BWRX-300 chemistry regime will ensure that the source term radiological dose to the worker and public is ALARP by optimising materials selection, operating chemistry, and operating practices.

3.3.3. PER Chapter E9 Prospective Radiological Assessment

54. PER Chapter E09 (ref. [71]) provides a radiological impact assessment of the radiation doses to members of the public due to normal operation of the BWRX-300. This includes the contributions from direct dose which falls within the scope of my assessment.

3.3.4. PSR Chapter 9A Auxiliary Systems

55. PSR Chapter 9A (ref. [5]) describes the BWRX-300 Auxiliary Systems and how they will comply with design and safety requirements. This chapter includes details of the out of core criticality controls which are within the scope of my assessment.

3.4. Basis of assessment: RP's documentation

56. The principal documents that have formed the basis of my radiological protection assessment of the SSSE are:

- PSR Chapter 12 Radiation Protection (ref. [6]) contains the highest-level summary of radiological protection to workers within the SSSE case. The following supporting references for Chapter 12 were sampled.
    - As Low As Reasonably Achievable (ALARA) Design Criteria for Standard Design (ref. [72]).
    - Annual Occupational Collective Radiation Dose for BWRX-300 (ref. [73]).
    - BWRX-300 Standard Design Optimization to Keep Radiation Exposures As-Low-As-Reasonably-Achievable (ref. [74])
- PER Chapter E9 Prospective Radiological Assessment (ref. [71])
- PSR Chapter 9A Auxiliary Systems (ref. [5]).
- PSR Chapter 23 Reactor Chemistry (ref. [7]).
- PSR Chapter 3 Safety Objectives and Design Rules for Structures, Systems and Components (ref. [4]).
- General arrangement drawings for the Reactor Building (ref. [75]), Power Block including Turbine Building and Radwaste Building (refs. [76], [77]).

3.5. Design Maturity

57. My assessment is based on revision 2 of the DRR (ref. [9]). The design reference report presents the baseline design for Step 2, outlining the physical system descriptions and requirements that form the design at that point in time.

58. The reactor building and the turbine building, along with the majority of the significant structures, systems, and components (SSCs) are housed with the 'power block'. The power block also includes the radwaste building, the

control building and a plant services building. For security, this also includes the PA boundary and the PA access building.

59. The GDA Scope Report (ref. [49]) describes the RP's design process that extends from baseline (BL) 0 (where functional requirements are defined) up to BL 3 (where the design is ready for construction).

60. In the March 2024 design reference, SSCs in the power block are stated to be at BL1. BL1 is defined as:

- System interfaces established;
- (included) in an integrated 3D model;
- Instrumentation and control aspects have been modelled;
- Deterministic and probabilistic analysis has been undertaken; and
- System descriptions developed for the primary systems.

61. The balance of plant remains at BL0 for which only plant requirements have been established, and SSC design remains at a high concept level.

62. With respect to radiological protection, there is still a need to fully substantiate and optimise: radiological source terms (Section 4.3.4), shielding requirements (Section 4.3.5), estimate dose rates, and task specific doses to workers (Section 4.3.3.2). As noted in Section 1.2 , it was agreed these items would be out of scope at Step 2, recognising the BWRX-300 is at concept design stage.

63.

4. ONR assessment

4.1. Assessment strategy

64. The objective of my Step 2 assessment was to reach an independent regulatory judgement on the fundamental aspects of the BWRX-300 design, relevant to radiological protection as described in Sections 1 and 3 of this report. My assessment strategy is set out in this section and defines how I have chosen which matters to target for assessment. My assessment is consistent with the delivery strategy for the BWRX-300 GDA (ref. [78]).

65. GVHA is currently engaging with regulators internationally, including the Nuclear Regulatory Commission in the US (NRC) and the Canadian Nuclear Safety Commission in Canada (CNSC). It is proposing a standard BWRX-300 design for global deployment with minimal design variations from country to country. My assessment takes cognisance of work undertaken by overseas regulators where appropriate.

66. Whilst there is no operating BWR plant in the UK, ONR has previously performed a four-step GDA on the Hitachi-GE UK ABWR (ref. [79]). I have taken learning from this previous activity, targeting my assessment on those aspects of the BWRX-300 which are novel or specific to this design. I have not looked to reassess inherent aspects of BWR technology which were considered in significant detail for the UK ABWR and judged to be acceptable.

67. In line with the Step 2 scope, my assessment plan (ref. [16]) has been to undertake an initial review of the radiological protection aspects within the SSSE case submissions with respect to the standards in Section 2.1. This review identified areas for further sampling where:

- the BWRX-300 design had potential to differ from established UK standards and RGP;
- the radiological protection features may significantly differ from UK ABWR (or other BWRs in operation); and
- further information was sought to provide confidence in the claims and arguments made in the safety case.

68. In practice, this entailed reviewing the SSSE case and raising Regulatory Queries (RQ) requesting further references, technical information, and clarifications regarding the radiological aspects of the SSSE case. Assessment observations and responses to the RQs were discussed with the RP at regular meetings during my assessment.

4.2. Assessment Scope

69. My assessment scope and the areas I have chosen to target for my assessment are set out in this section. This section also outlines the submissions that I have sampled, the standards and criteria that I will judge against and how I have interacted with the RP and other assessment topics.

70. My assessment scope is consistent with the GDA scope agreed between the regulators and the RP during Step 1 and detailed in Section 1.2 of this report. I have targeted my assessment within this scope.

71. In line with the objectives for Step 2, I have undertaken a broad review of the highest level, fundamental claims and supporting arguments related to radiological protection. To support this, I have sampled a targeted set of the claims or arguments as set out below. Where applicable, I have also sampled the evidence available to support any claims and arguments.

72. To fulfil the aims for the Step 2 assessment of the BWRX-300, I targeted my assessment on the following items, which I consider important:

- **Individual Doses**: I assessed the methodology and assumptions used to estimate normal operations doses to gain confidence that the design can be operated within IRR17 legal dose limits and in accordance with SAPs Targets 1, 2, and 3. Where detailed dose analysis was not available, I have considered the arguments (and available evidence) underpinning the claim that doses will meet regulatory expectations.

- **Designation of Areas**: I considered the use of OPEX and relevant guidance for radiological zoning to identify appropriate dose rate limits and contamination controls. I considered how dose rate limits are set to ensure dose rates are acceptable (e.g. shielding requirements), and that sufficient work has been completed to identify fundamental contamination controls.

- **Occupational Exposures:** I considered whether the RP has sufficiently identified all occupational exposures and pathways arising from normal plant operations. This took into account approach, methodology, incorporation of OPEX and relevant guidance, and how potential exposure to ionising radiation during normal operations may be reduced to ALARP.

- **Radiation Shielding**: I have undertaken a proportionate high-level assessment of the approach, methods, and maturity of the shielding analysis for BWRX-300. I considered the approach, methods, and computational codes used in shielding analysis.

- **Compact Design**: I considered how the reduced footprint and compact layout of the BWRX-300 may impact radiological protection.

- **Criticality**: I assessed the claims and arguments in the safety case regarding out of core criticality. This considered the approach, methods, computational codes, and criteria employed in criticality safety analysis.

4.3. Assessment

4.3.1. Radiological Protection Aspects of the SSSE Cases

73. PSR Chapter 12 (ref. [6]) summarises the design and safety information for radiological protection for normal operation of the BWRX-300. Additional information regarding radiological source terms are provided in PSR Chapter 23 (ref. [7]) and direct radiation doses to the public presented in PER Chapter E09 (ref. [71]).

74. PSR Chapter 12 uses the format, structure, and headings recommended in SSG-61. The content sufficiently aligns with IAEA guidance provided in SSG-61 (ref. [64]) and relevant radiological protection guidance in SSR-2/1 (ref [63]) and SSG-90 (ref. [66]); noting that further details will need to be incorporated as the safety case develops (e.g. licensee input such as radiation protection programmes).

75. With regards to the claims, arguments, and evidence (CAE), the approach taken by the RP is to provide overarching claims that are consistent across the PSR chapters. Supporting arguments are then presented in each of the relevant chapters to illustrate how the claims will be substantiated (Table A-1 of PSR Chapter 12). I consider this approach to be sufficient for the purposes of a Step 2 assessment, however, as the design and safety case develops, specific claims for radiological protection would be required, along with further arguments and evidence to substantiate these claims.

76. The safety case provides suitably detailed summaries of the radiological protection objectives, design criteria, and engineering features for the purposes of Step 2 assessment. A future BWRX-300 safety case will need to provide evidence of analysis and substantiation of radiological protection features underpinning safety claims, as well as further details of radiation protection policies, procedures, and programmes during licensing.

77. There has been good engagement with the RP during Step 2 to expand the FAP in PSR Chapter 12 (ref. [6]) to identify further work that will be required by the designers or future licensee to meet UK requirements. The FAP provides additional confidence that UK specific requirements and associated RGP will be incorporated during future design and safety case development of the BWRX-300.

78. **In conclusion,** I judge the format, structure, and content of the radiological protection aspects of the SSSE case I assessed to be consistent with UK regulatory expectations and IAEA guidance. The CAE are sufficient for purposes of Step 2; however, it would be beneficial to develop more specific claims for radiological protection. At Step 2, the safety case currently lacks

sufficient evidence to support the safety claims and arguments in PSR Chapter 12 as captured in the FAP; this will need to be addressed in a future safety case submission.

4.3.2. Compliance with the IRR17

79. My assessment considered whether the conceptual design of the BWRX-300 will be capable of being built and operated in accordance with the requirements of IRR17. These regulations have a wide range of requirements for working with ionising radiation, many of which focus on operational aspects which will be determined by a future licensee. As the BWRX-300 is still at the conceptual design phase, many of these regulations are not relevant at this stage and are outside the scope of a Step 2 assessment. Therefore, my assessment sampled the following key areas to judge whether the BWRX-300 design is capable of meeting the requirements of IRR17 (ref. [62]) and associated RGP outlined in the ONR SAPs (ref. [12]) and IAEA guidance SSR-2/1 and SSG-90 (refs. [63], [66]).

- IRR17 Regulation 9 - Restriction of exposure
- IRR17 Regulation 12 - Dose limitation
- IRR17 Regulation 17 - Designation of controlled or supervised areas

4.3.2.1. IRR17 Regulation 9 - Restriction of Exposure

80. IRR17 Regulation 9 ‘Restriction of exposure’ covers a range of requirements. For a fundamental assessment of the BWRX-300 design, I have limited the scope of my assessment to gaining assurance that the RP is able to comply with IRR17 regulations 9(1), 9(2)(a), 9(4) and 9(5).

81. IRR17 Regulation 9(1)

- IRR17 Regulation 9(1) specifies that “every employer must, in relation to any work with ionising radiation that it undertakes, take all necessary steps to restrict so far as is reasonably practicable the extent to which its employees and other persons are exposed to ionising radiation”.
    - IRR17 Regulation 9(1) ACoP paragraph 85, states that “dose-sharing should not be used as a primary means to keep exposures below legal limits.”
    - IRR17 Regulation 9(1) ACoP paragraph 86, states “Employers should take particular steps to restrict the exposure of any employees who would not normally be exposed to ionising radiation in the course of their work. The dose control measures should make it unlikely that such people would receive an effective dose greater than 1 mSv per year…”

82. Further work is required to demonstrate that doses have been restricted SFAIRP in compliance with Regulation 9(1). However, based on my sampling of the submissions (see Section 4.3.3 Optimising Exposures to ALARP), I judge that SFAIRP (or ALARA) is a priority for the RP in their underpinning design approach, safety case submissions, and FAP. It is also clear that the design development does not employ dose sharing to meet regulatory requirements as compliance with dose limits will be based on minimum staffing levels (Section 4.3.3.2). Furthermore, suitable designation of areas (Section 4.3.2.3), shielding (Section 4.3.), layout, and access controls should ensure that doses to employees who would not normally be exposed to ionising radiation in the course of their work can be restricted.

83. IRR17 Regulation 9(2)

- IRR17 Regulation 9(2) specifies that "an employer in relation to any work with ionising radiation that it undertakes must: (a) so far as is reasonably practicable achieve the restriction of exposure to ionising radiation required under IRR17 Regulation 9(1) by means of engineering controls, design features and by the provision and use of safety features and warning devices;".
    - IRR17 Regulation 9(2) guidance paragraph 101 recommends that for "any work with ionising radiation, employers should take action to control the doses received by their employees and other people by means of engineering controls first. Only after these have been applied should they consider using supporting systems of work. Lastly, employers should provide PPE to further restrict exposure where this is necessary and reasonably practicable."
    - IRR17 Regulation 9(2) guidance paragraph 102 recommends "establishing control measures at an early stage which will help employers to effectively restrict exposure, for example when the facility or device is being planned and designed. This means that the dose control mechanisms can be incorporated into the construction of the facility."

84. With respect to IRR17 Regulation 9(2), based on sampling the submissions, I judge that the RP's approach to the development of radiological protection for BWRX-300 is consistent with the regulations, ACoP, and guidance; these include restricting exposures through engineered means such as provision of shielding, ventilation, remote operation, radiation monitoring and alarms, and access controls consistent with IRR17 guidance on hierarchy of control measures. Further discussion of the RP's approach to optimising occupational exposures to ALARP is provided in Section 4.3.3.

85. IRR17 Regulations 9(4) and 9(5)

- Regulation 9(4) "Where it is appropriate to do so at the planning stage of radiation protection, an employer, in relation to any work with ionising radiation that it undertakes, must use dose constraints in restricting exposure to ionising radiation pursuant to paragraph (1).

- Regulation 9(5) “An employer must establish the dose constraints referred to in paragraph (4) in terms of individual effective or equivalent doses over a defined appropriate time period.

86. IAEA guidance SSG-90 (ref. [66]) also recommends setting additional design targets (akin to IRR17 dose constraints) at the start of the design process, which takes account of OPEX at similar nuclear power plants that have a good operating record in terms of radiation protection. These design targets should include annual collective and individual doses to workers and annual individual doses to members of the public.

87. The BWRX-300 design criteria (ref. [74]) states that doses will not exceed regulatory dose limits for workers and the public, and sets a collective dose target for workers of a fraction of 1 person-Sv/y. It does not outline any individual dose targets (below regulatory limits) for workers or the public. In absence of a suitably detailed dose assessment at Step 2, I would expect the RP to clearly outline OPEX informed dose targets for the purposes of design development and allow comparison with SAPs Targets 1, 2, and 3 at an early design stage.

88. **In conclusion,** based on my sampling of the Step 2 submissions and discussions with the RP, I see no fundamental reason future development of the BWRX-300 design will not be capable of meeting IRR17 Regulation 9 requirements. However, it is recommended that a future safety case define suitable and justifiable dose constraints that comply with IRR17 requirements and IAEA guidance; I would expect this to be addressed within the scope of the FAP PSR12-2 and PSR12-423 (Appendix B of PSR Chapter 12 (ref. [6])).

4.3.2.2. IRR17 Regulation 12 - Dose Limitation

89. IRR17 Regulation 12 Dose Limitation states that “…every employer must ensure that its employees and other persons within a class specified in Schedule 3 are not exposed to ionising radiation to an extent that any dose limit specified in Part I of that Schedule for such class of person is exceeded in any calendar year.” The dose limits in Part I of Schedule 3 are summarised in Table 1.

Table 1: IRR17 Part I of Schedule 3 - classes of persons to whom dose limits apply.

Class of Person	Effective dose	Equivalent dose for lens of the eye	Equivalent dose for the skin *	Equivalent dose for the extremities
Employees and trainees of 18 years and above	20 mSv/y	20 mSv/y	500 mSv/y	500 mSv/y
Trainees aged under 18 years	6 mSv/y	15 mSv/y	150 mSv/y	150 mSv/y
Other persons	1 mSv/y	15 mSv/y	50 mSv/y	50 mSv/y

* Equivalent dose for the skin (averaged over 1 cm^2)

90. The ONR SAPs (ref. [63]) provides numerical targets that ONR inspectors use as an aid to form a judgement when considering whether radiological hazards are being adequately controlled and risks reduced to ALARP. SAPs targets quantify ONR's risk policy in terms of a Basic Safety Level (BSL) and a Basic Safety Objective (BSO). A new facility or activity should at least be below the BSLs, noting that the BSL for Targets 1 and 3 are legal limits outlined in IRR17 Part I of Schedule 3 (ref. [62]). The BSOs form benchmarks that reflect modern safety standards and expectations and recognise that there is a level below which further consideration of the safety case would not be a reasonable use of ONR resources.

91. The SAPs BSL and BSO for Targets 1, 2, and 3 are provided in Tables 2, 3 and 4. Targets 1 and 2 consider doses to workers on site, where as Target 3 focuses on any person off site including members of the public.

Table 2: Target 1 - Normal operation - any person on the site

Normal operation – any person on the site	**Target 1**
The targets and a legal limit for effective dose in a calendar year for any person on the site from sources of ionising radiation are: Employees working with ionising radiation: BSL(LL): 20 mSv BSO: 1 mSv Other employees on the site: BSL: 2 mSv BSO: 0.1 mSv *Note that there are other legal limits on doses for specific groups of people, tissues and parts of the body (IRR17). Normal operational doses should also be reduced ALARP.*	

Table 3: Target 2 - Normal operation - any group on the site

Normal operation – any group on the site	Target 2
The targets for average effective dose in a calendar year to defined groups of employees working with ionising radiation are: BSL: 10 mSv BSO: 0.5 mSv	

Table 4: Target 3 - Normal operation - any person off the site

Normal operation – any person off the site	Target 3
The target and a legal limit for effective dose in a calendar year for any person off the site from sources of ionising radiation originating on the site are: BSL(LL): 1 mSv BSO: 0.02 mSv *Note that there are other legal limits to tissues and parts of the body (IRR17).*	

92. For the purposes of this assessment, I have focused on gaining confidence that the BWRX-300 design can be operated by a future licensee below the BSL for Targets 1, 2, and 3.

93. Targets 1 and 2 – Worker Doses

94. An assessment for Targets 1 and 2 requires the RP to provide dose predictions to demonstrate that the radiation doses, likely to be received by the employees on the site, will meet the targets (ref. [60]) which should be based on:

- a knowledge of the radioactive sources and their distribution within the facility of interest;
- the facility design and the proposed system of operation (including radiation shielding); and
- the specific tasks expected to be undertaken by the operators.

95. The safety case conservatively estimates the annual collective dose to workers to be 491 person-mSv/y (further details of the dose assessment is provided in Section 4.3.3.2), however, it does not provide estimates for individual worker doses for comparison to SAPs Targets 1 and 2. My assessment therefore focuses on whether the BWRX-300 is likely to be able to meet UK regulatory expectations in the future.

96. The BWRX-300 design criteria (reg. [72]) has been developed to meet the regulatory dose limits for the US and Canada and ALARA. PSR Chapter 12 clarifies that the BWRX-300 design has set an individual worker dose limit of 20 mSv/y which aligns with SAPs Target 1 BSL and IRR17 regulatory dose limit. There are no further design targets below the regulatory dose limit that align with SAPs Target 2; however, the RP has committed to a forward action (PSR12-2) to “develop a UK methodology enabling the evolution of the BWRX-300 standard design into a UK implementation that meets the IRR17 requirements and ONR SAP targets.” As noted in the Section 4.3.2.1, this should include defining suitable and justifiable dose constraints that comply with IRR17 requirements and IAEA guidance.

97. I have sampled the collective and individual doses for operating BWRs provided in NUREG-0713 series 2017-2022 (ref. [80]) and Information System on Occupational Exposure (ref. [81]) and note that individual doses to workers rarely exceed 20 mSv/y with the vast majority of workers doses being below 10 mSv/y. ONR has also undertaken a GDA assessment of the UK ABWR (ref. [82]), where a predicted collective dose of 501 person-mSv/y corresponded to a maximum individual worker dose of 11 mSv/y. Based on my sampling it is reasonable to expect that a BWR designed to modern standards can be operated within the legal limits outlined in IRR17 and below the BSLs for Targets 1 and 2.

98. A future safety case will need to provide sufficiently detailed dose assessments to demonstrate that the worker doses will be within IRR17 regulatory limits in line with Target 1 and include details of doses to defined worker groups for comparison to Target 2.

99. **Target 3 - Direct Radiation Dose to the Public**

100. Doses to members of the public are addressed in PER Chapter E09 Prospective Radiological Assessment (ref. [71]) with links to PSR Chapter 12 (ref. [6]). The BWRX-300 design criteria (ref. [72]) outlines a dose limit of 1 mSv/y for the members of the public off-site in line with the IRR17 legal limit.

101. Estimating doses to members of the public must consider doses from all exposure pathways. For the purposes of BWRX-300, this consists of the dose from direct radiation addressed in my assessment, and doses from discharges, which have been assessed by the Environment Agency (ref. [83]). The separate estimates should be combined to ensure that doses are below IRR17 dose limit and the BSL for Target 3.

102. At this stage in the design, no assessment has been conducted with regards to the potential dose rates at the site boundary due to direct radiation from BWRX-300 facilities. Instead, OPEX data from US NRC environmental reports for 20 operational BWR sites across the US was used to show the dose rates at the site boundary. An average of the 20 dose rates was used to indicate a dose rate for the BWRX-300, which was reported as 0.08 µSv/h.

103. The dose rate was then multiplied by an occupancy rate, which is calculated and weighted based on the behavioural traits of a reference person. The reference person selected was a dog walker spending 2-hours per week at the site boundary, giving an occupancy rate of 104 h/y. This was assumed to be a credible scenario by the RP, noting that this will need to be refined and supported by evidence at a later licensing stage.

104. The annual direct radiation dose to a member of the public from normal operations was therefore estimated to be 8.6 µSv/y, which is based on the average dose rate of 0.08 µSv/h, multiplied by the occupancy rate for the reference person of 104 h/y (ref. ref. [71]). This is below the BSO for Target 3 of 20 µSv/y and well below the BSL for Target 3 of 1 mSv/y. The FAP PSR12-421 (ref. [6]) and PER9-120 (ref. [71]) recognises the need to undertake further analysis to the estimate and optimise direct doses to the public. This will include revising the dose rate based on modelling and assessment of the sources of direct radiation at the site boundary from BWRX-300 facilities and an evidence-based review of the occupancy rate.

105. In the absence of analysis of potential dose rates for the BWRX-300 design, I consider the use of OPEX data from operating BWRs to give an indication of direct radiation doses that are below BSL and BSO for Target 3 to be sufficient for a Step 2 GDA assessment. Therefore, this provides confidence that direct dose to the public will be below the BSL, subject to further substantiation through completion of the FAP.

106. **In conclusion,** it is my opinion that the BWRX-300 will be designed - to modern standards and capable of being operated within regulatory dose limits outlined in IRR17 and below the BSLs for Targets 1, 2, and 3. In absence of substantiated dose assessments, a future safety case will need to provide sufficiently detailed dose assessments to demonstrate compliance with all dose limits outlined in IRR17, and justification that the individual doses to both workers and the public have been reduced to ALARP.

4.3.2.3. IRR17 Regulation 17 - Designation of Areas

107. IRR17 Regulation 17 (ref. [62]) considers the designation of controlled and supervised areas. IRR17 Regulation 17(1) requires employers to designate controlled areas if:

- “it is necessary for any person who enters or works in the area to follow special procedures designed to restrict significant exposure to ionising radiation in that area or prevent or limit the probability and magnitude of radiation accidents or their effects; or

- any person working in the area is likely to receive an effective dose greater than 6 mSv a year or an equivalent dose greater than 15 mSv a year for the lens of the eye or greater than 150 mSv a year for the skin or the extremities.”

108. IRR17 ACoP 17 (1) paragraph 297 also advises that “an area should be designated as a controlled area if the dose rate (averaged over a minute) exceeds 7.5 µSv per hour… “.

109. IAEA guidance in SSG-90 (ref. [66]) also states that a logical layout for the plant should be developed, dividing the plant into zones on the basis of predicted dose rates and contamination levels. During the design phase dose rates may be calculated or based on OPEX from similar plants. This is consistent with ONR SAPs RP.3 guidance (ref. [12]) that “where appropriate, designated areas should be further divided, with associated controls, to restrict exposure and prevent the spread of radioactive material.”

110. My assessment considers:

- Radiation zoning used to set dose rate limits for external radiation
- contamination zoning used to set limits on surface and airborne contamination, separately.

111. The BWRX-300 radiation zoning scheme presented in PSR Chapter 12 defines external dose rate limits for zones ranging from A (not a radiation area) to J (very high radiation area) in line with US NRC (ref. [84]) and IAEA (ref. [66]) guidance for reactor design. For the purposes of UK deployment, the RP proposes designating zone A as a supervised areas and zones B to J (where dose rates may be above 6 µSv/h) as controlled areas which aligns with the IRR17 ACoP. Based on sampling of the radiation zoning for the BWRX-300 as presented in PSR Chapter 12 (ref. [6]) with reference to general arrangement drawings (refs. [76] [77]) the radiation zoning is consistent with guidance provided in ONR SAPs and IAEA SSG-90.

112. The BWRX-300 standard design does not specify a contamination zoning scheme in line with UK RGP. I have considered the information provided in PSR Chapter 12 (ref. [6]), BWRX-300 ALARA design criteria (ref. [72]) and response to RQ-02081 (ref. [85]). I am satisfied that RP’s arrangements and conceptual design identify areas of plant where there is potential for increased levels of contamination (e.g. leaks and spills) in which to focus radiological protection measures (e.g. ventilation, drainage) to minimise exposures and limit the spread of contamination. A future safety case will need to establish a contamination zoning scheme for the BWRX-300 in line with UK RGP; the RP recognises the need for this further work and has committed to this in FAP PSR12-422 (ref. [6]).

113. **In conclusion,** I judge that the BWRX-300 standard design will be capable of meeting IRR17 Regulation 17(1) requirements and align with UK and international guidance subject to the completion of further work identified in the FAP.

4.3.2.4. Summary

114. The BWRX-300 safety case is not expected to fully demonstrate compliance with all the relevant IRR17 requirements at the conceptual design phase. The SSSE case refers to future compliance with IRR17, however, further work is required to fully review the design of the BWRX-300 with respect to complying with IRR17 requirements. This has been captured in the FAP PSR12-423 (ref. [6]).

115. Based on my sampling at Step 2, I have not identified any fundamental shortfalls that would prevent future compliance with IRR17 requirements. I consider the BWRX-300 conceptual design to be capable of meeting IRR17 requirements consistent with relevant ACoPs and guidance subject to completion of further work identified in the FAP PSR12-2 and PSR12-423 (ref. [6]).

4.3.3. Optimising Occupational Exposures to ALARP

116. I have sampled the following documents to consider the RP's approach to estimation and optimisation occupational exposures to ALARP.

- PSR Chapter 12 Radiation Protection (ref. [6]).
- Annual Occupational Collective Radiation Dose for BWRX-300 (ref. [73]).
- As Low As Reasonably Achievable Design Criteria for Standard Design (ref. [72]).
- BWRX-300 Standard Design Optimization to Keep Radiation Exposures As-Low-As-Reasonably-Achievable (ref. [74]).

4.3.3.1. Approach to ALARP

117. PSR Chapter 12 (ref. [6]) summarises the strategies and design considerations employed in the development of the BWRX-300 to ensure occupational radiation exposure to plant personnel is kept ALARP. This is supported by the BWRX-300 design criteria (ref. [72]) which establishes the BWRX-300 ALARA implementation policy, radiation protection design description, and ALARA design requirements.

118. The safety case outlines ALARA Objectives (AOs) and design requirements which focus on meeting US NRC and CNSC regulatory requirements with reference to relevant IAEA guidance. These include restricting exposures through engineered means such as provision of shielding, ventilation, remote operation, radiation monitoring and alarms, and access controls. I consider the AOs and design requirements to be sufficiently comprehensive, clear, and consistent with relevant radiological protection SAPs (RP.1, RP.3, RP.6, and RP.7) and IRR17 regulations and guidance (e.g. Regulation 9) for Step 2 fundamental assessment.

119. The BWRX-300 design criteria also outlines ALARA dose targets which include not exceeding regulatory dose limits, a collective dose target for workers, and that doses are ALARA. As discussed in Section 4.3.2.1, further work is required to meet IRR17 requirements with regards to dose constraints and align with IAEA guidance SSG-90 (ref. [66]).

120. The BWRX-300 Standard Design Optimization to Keep Radiation Exposures As-Low-As-Reasonably-Achievable (ref. [74]) provides details of the process used to assess potential design modifications to ensure that the ALARA design requirements are met. Although no evidence of this process being applied was sampled during Step 2, the submissions indicate that the RP has established processes and principles for assessing design features to reduce exposures to ALARP. A future safety case will need to provide evidence to demonstrate this process sufficiently aligns with relevant UK guidance.

121. **In conclusion,** I judge that the RP has provided sufficient information at Step 2 to indicate that international RGP has been used to inform radiological protection objectives and design requirements, and they have an established process for assessing and optimising the design to aid in reducing exposures to ALARP. As recognised in the FAP (ref. [6]); there will be a need to review and update the design criteria and processes to accommodate UK regulatory requirements (e.g. IRR17) and those of a future licensee.

4.3.3.2. Dose Assessments

122. PSR Chapter 12 (ref. [6]) presents an estimate of the annual occupational collective dose to workers for the BWRX-300 with further details of the analysis provided in the Annual Occupational Collective Radiation Dose for BWRX-300 report (ref. [73]). For convenience I will use the term ‘collective dose’ to refer to annual occupational collective radiation dose to workers within this section.

123. The total collective dose estimates are presented as collective doses for six activity categories (Table 5). A further six tables for each activity category present a breakdown of the doses by facility area/activity with estimated average dose rates and exposure times.

124. The collective dose estimates are based on BWR OPEX (including maintenance records, exposure measurements) which has been modified to account for BWRX-300 design features and requirements. For example, task durations have been adjusted due to removal/reduction of systems, such as reductions in steam lines and Fine Motion Control Rod Drives compared to other BWRs. Similarly, dose rates have been adjusted based on differing BWRX-300 plant arrangement and radiation zone requirements.

Table 5: BWRX-300 Total Occupational Radiation Exposure Estimates (ref. [6])

Activity	Estimated Collective Hours Annually (person-hours/year)	Projected Annual Collective Dose (person-mSv/year)	Percent of Total Collective Dose (%)
Reactor Operations and Surveillances	2,609	38	7.8
Routine Maintenance	7,085	90	18.2
Waste Processing	2,456	60	12.1
Refuelling	2,580	47	9.6
In-Service Inspection	759	32	6.4
Special Maintenance	11,624	225	45.8
Total	**27,113**	**491**	**100.0**

125. The RP has clarified in RQ-01805 (ref. [86]) that conservatisms in the collective dose estimate include, use of older BWRs OPEX (which do not possess modern dose reduction features included in BWRX-300), and consolidation of activities (e.g. routine and special maintenance) and refuelling into a single year of operation. As such, the collective dose estimate is an enveloping estimate that is not expected to be exceeded in any single year of facility operation.

126. The RP has not completed sufficient analysis at Step 2 to validate the task times or dose rates used in the collective dose assessment for the BWRX-300 design. The RP has noted that further work beyond Step 2 will be undertaken to update task times through the Reliability, Availability, Maintainability, and Inspectability (RAMI) Program and staffing requirements by the Human Factors Engineering (HFE) Program. Similarly, dose rates will be verified based on BWRX-300 specific shielding and dose rate calculations yet to be completed.

127. Anticipated Occupational Occurrences (AOOs), which is the international term similar to ‘minor deviations’ as described in NAST-TAST-GD-043 (ref. [60]), are also not explicitly considered within the collective dose estimate. However, the operating data, maintenance records and exposure measurements used as the basis for the collective dose estimate includes contributions from all plant conditions. This would include spills or leaks that occurred during execution of the various work activities and any elevated dose rates the plant may have experienced due to fuel leaks. Further analysis will be required in a future safety case submission to explicitly address the potential doses received from AOOs.

128. The following summarises my observations from reviewing the collective dose assessment against RGP guidance in IRR17 (ref. [62]), NS-TAST-GD-043 Radiological Analysis - Normal Operation (ref. [60]), and IAEA SSG-90 (ref. [66]):

- I consider production of a preliminary collective dose assessment at the conceptual design stage to be RGP. It is informative and provides confidence that the CAE in the SSSE case will be achieved as the design progresses.

- The RP has used OPEX and conceptual design information to identify and estimate occupational exposures for different modes of normal operation. This has a sufficient breakdown to highlight higher dose activities and/or facility areas in which to focus further dose optimisation.

- It is evident that OPEX and design information from other BWRs (including ABWR) has been used to estimate doses; though it was noted that some information dates back to the 1970s. However, this will be refined and updated with BWRX-300 specific design information (e.g. RAMI and HFE programs).

- I am satisfied with the RP’s claims that the preliminary collective dose estimate is conservative. However, current estimates do not include potential doses from Anticipated Operation Occurrences (AOOs) which will need to be considered in a future safety case submission.

129. Whilst there are no regulatory limits for collective dose, it can be a useful performance metric for comparison with other operating NPPs. The annual collective dose to workers is estimated to be 491 person-mSv/y for the BWRX-300. PSR Chapter 12 compares the BWRX-300 annual collective dose with other operating BWRs taken from ISOE (Figure 1).

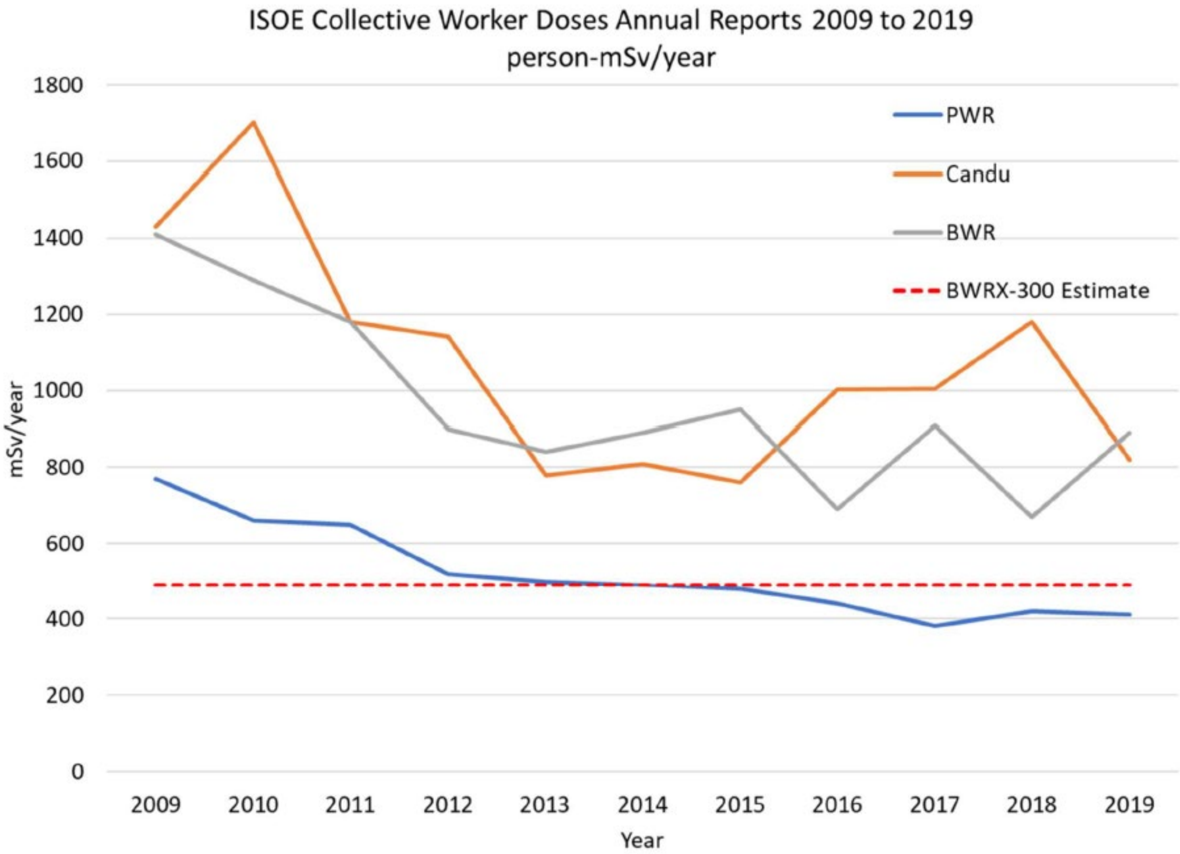

Figure 1: Comparison of BWRX-300 Results to ISOE Industry Operating Data (ref. [6])

130. The comparison indicates that the BWRX-300 doses will be significantly lower than the average annual collective dose for all operating BWRs in ISOE database of ~800 person-mSv/y (2015-2019). However, I would consider it more suitable to benchmark the BWRX-300 against similar, modern, or better/best performing BWRs. For example, the annual collective dose for the BWRX-300 is similar to that of the more modern and much larger UK ABWR (ref. [79]) with annual collective dose of 500 person-mSv/y. I would expect the doses for the BWRX-300 to be significantly lower than the UK ABWR, due to being significantly smaller and having fewer systems to operate and maintain as described in PSR Chapter 12. However, I do recognise that at Step 2, the annual collective dose estimate for the BWRX-300 is preliminary, conservative, and subject to further refinement and optimisation during detailed design, which may reduce annual collective doses to workers.

131. The collective dose estimates in conjunction with minimum staffing levels (to be established by the HFE team) will provide an average estimate of the individual doses to all workers; however, further work will be required to demonstrate compliance with IRR17 dose limits and ONR SAPs targets. For example, a future submission will need to provide a sufficiently detailed worker dose assessment to demonstrate that the average doses to defined groups of workers is below the BSL for Target 2 (Table 3); I would expect this to be addressed in the FAP as part of PSR12-2 (ref. [6]).

132. **In conclusion,** the safety case benefits from the early consideration of the annual collective dose to workers. I judge that the approach for the dose assessment at conceptual design phase is consistent with UK and international guidance. A future safety case will need to provide sufficiently detailed dose assessments, and justification that the individual doses are acceptable and reduced to ALARP.

4.3.4. Normal Operation Radiological Source Terms

133. Management of radiation sources associated with the operation of a nuclear reactor is a fundamental aspect of radiological protection. As it is not practicable to eliminate the sources of ionising radiation, the design should focus on reducing the magnitude of radiation sources, to reduce radiation levels and, thereby minimise exposures to workers and the public.

134. PSR Chapter 12.2 (ref. [6]) summarises the sources of radiation within the BWRX-300 with reference to PSR Chapter 23 (ref. [7]). It also references several supporting documents relating to specific radiation sources (e.g. Fuel Pool, Control Rod Drive System Sources) which were not submitted at Step 2.

135. I have undertaken a high-level assessment of the Primary Source Term (PST) used to derive Process Source Terms (PrST) which will underpin many of the radiological protection assessments, including worker dose, public dose, and shielding design. My assessment considered previous ONR assessment of the UK ABWR source terms (ref. [82]) and the Step 2 assessment of the BWRX-300 source terms by the chemistry topic lead (ref. [87]).

136. Assessment of the PST presented in PSR Chapter 23 was led by the chemistry specialist inspector. Their assessment (ref. [87]) concluded that the methodologies used in deriving source terms are reasonable and that the source terms presented are conservative. I am satisfied that the chemistry assessment sufficiently covers my interest in the derivation and justification of the normal operations radiological source term topic area. Additionally, PSR Chapter 12 (ref. [6]) describes the design features for radiation protection which will minimise sources of radiation and contribute to reducing doses to ALARP, which I judge to be sufficient for Step 2 GDA assessment.

137. The deposition of activated corrosion products, such as Co-60, are the largest contributors to shutdown doses to workers. The BWRX-300 employs the use of low cobalt materials in contact with reactor coolant; with minimisation of cobalt to <0.05 % in general and <0.03 % in in-core components (ref. [6]). The BWRX-300 also employs the use of depleted zinc oxide which reduces the build-up of Co-60 on reactor circuit system surfaces, whilst minimising activation of Zn-64 to Zn-65 which can affect source terms.

138. N-16 is a high energy gamma emitting nuclide with a short ~7s half-life which can impact both worker and public doses and drive shielding requirements when the reactor is at power. As with the UK ABWR, the BWRX-300 is designed to operate under hydrogen water chemistry (HWC) to control inter-granular stress corrosion cracking (IGSCC). However, implementation of HWC increases N-16 concentrations in the reactor steam. On-Line NobleChem™ (OLNCTM) is used to reduce the amount of hydrogen addition required to mitigate IGSCC which also reduces N-16 concentrations.

139. At Step 2 the N-16 concentration in steam for the BWRX-300 design basis (DB) source term is significantly higher than the realistic model (RM) source term; it is also higher than N-16 for the UK ABWR (ref. [88]). In response to an RQ (ref. [89]) the RP clarified that further optimisation of the HWC injection rates have been made by leveraging OLNCTM injection which will reduce levels of N-16 in steam bearing equipment. The RP has captured the need to revise DB source terms in the FAP (PSR12-424 in Appendix B of (ref. [6])).

140. **In conclusion**, I judge that radiological source terms for the BWRX-300 are sufficiently developed and conservatively derived for the purposes of design development (e.g. shielding design). I consider the BWRX-300 design choices to minimise source terms to be consistent with UK and international guidance. There remains a need to develop a full suite of substantiated and optimised source terms to underpin shielding and dose assessments for all modes of operation; this has been identified in FAP PSR23-133 (ref. [7]) and PSR12-424 (ref. [6]).

4.3.5. Radiation Shielding

141. The radiation shielding analysis for the BWRX-300 has not been completed and no substantiation of the dose rates or shielding provisions is referenced in SSSE case submissions. I have therefore focussed on the RP's approach to implement an optimised shielding design in line with RGP provided in SSG-90 (ref. [66]), SAP RP.6 Shielding (ref. [12]) and NS-TAST-GD-002 Radiation Shielding (ref. [56]). My Step 2 assessment sampled the information provided in PSR Chapter 12 (ref. [6]), BWRX-300 design criteria (ref. [72]) and RQ-01996 Radiation Shielding (ref. [89]); the findings are summarised below.

142. The radiation zoning provided in PSR Chapter 12 (ref. [6]) determines the dose rate limits for each area of the BWRX-300 based on OPEX (see Section 4.3.2.3); therefore, the radiation zones define shielding criteria. Calculation codes use conservatively derived source terms to determine radiation shielding requirements and estimate dose rates for each area. Source terms are converted using ORIGEN for use in shielding calculations performed using MCNP (ref. [89]) with the ENDF/B-VII cross-section library; both ORIGEN and MCNP are widely used in the nuclear industry and considered RGP. The RP Shielding calculations use ANSI/ANS-6.1.1 1977 dose coefficients as opposed to those recommended by International

Commission on Radiological Protection (ICRP) which are considered to be UK RGP. Differences in dose coefficients are unlikely to significantly affect the shielding analysis for the generic design of the BWRX-300 and will be reviewed as part of the FAP PSR12-425 (ref. [6]). Overall, I judge that the general approach to performing shielding calculations align with ONR expectations and relevant guidance.

143. The RP has not provided any results of the shielding analysis at Step 2, but have confirmed in RQ-01996 (ref. [89]) that the shielding analysis is currently ongoing and will be subject to further optimisation throughout the BWRX-300 design process. Refinement and optimisation of source terms should see shielding requirements and dose rates for the BWRX-300 reduce as the design progresses. For example, peak dose rates and shielding provisions for the Turbine Building during normal power operation are driven by the presence of activated N-16 within the steam phase of the coolant. As noted in the section 4.3.4, further optimisation of the DB source terms beyond Step 2 should see potential reductions in peak dose rates and shielding requirements for the Turbine Building; this additional work is captured in the RP's FAP PSR12-424 (ref. [6]).

144. During normal power operation, the reactor cavity pool above the RPV is filled with water providing shielding and reducing dose rates to operators working above the pool to 25 μSv/h. In response to RQ-01996 (ref. [89]) the RP confirmed that in the event the reactor cavity pool was to experience a loss of water the areas around it would require evacuation until the condition is corrected. The RP has been advised that a future submission will need to provide further details demonstrating that the design has suitable means to prevent unintentional loss of the liquid shielding, detect such losses, and initiate an alarm in line with guidance provided in the ONR SAPs and NS-TAST-GD-002 Radiation Shielding.

145. **In conclusion,** the RP has used OPEX to inform the shielding requirements, alongside industry recognised codes and approaches to assess shielding provisions in line with UK and international guidance. I judge this to be sufficient for Step 2 assessment; however, a future safety case will need to demonstrate with evidence that shielding provisions have been substantiated and where appropriate optimised as the design progresses.

4.3.6. Compact and Modular Design

146. My assessment has considered whether the compact or modular design of the BWRX-300 will significantly impact radiological protection for the generic design of the BWRX-300.

147. With regards to compact design, the RP claims that the reduced footprint of the BWRX-300 (when compared to other BWRs) is largely due to removal or reduction of systems. The RP uses 3D modelling to review and ensure there is adequate space to undertake work in active areas of the plant; this

includes reserving space for storage, movement, and laydown of equipment to perform maintenance.

148. It is also worth noting that shielding provisions (e.g. walls/floors) are based on meeting dose rate criteria and there is no evidence of shielding being reduced to facilitate a more compact layout. Furthermore, modular construction design features which may impact shielding (e.g. introduce radiation weak paths or gaps) should be manageable with the RP's general assessment arrangements.

149. **In conclusion,** I have not found any evidence that compact or modular design of the BWRX-300 will significantly impact radiological protection. I judge that the RP's general arrangements for reviewing and assessing radiological protection should be sufficient to manage potential issues arising from compact or modularisation design features.

4.3.7. Out of Core Criticality

150. As stated in PSR Chapter 9A (ref. [5]), the BWRX-300 is a 300 MW reactor which uses standard BWR uranium oxide GNF2 fuel assemblies (10x10 array) enriched up to 5.0 w/o U-235/U. There will be 240 fuel assemblies within the reactor, shuffled every 12-24 months with up to a third of the core removed at each outage. The operational life is designed to be 60 years.

151. The fuel contains burnable absorbers so for the purposes of criticality safety, the fuel is assumed to be irradiated until peak reactivity is achieved. Although burnup credit is not claimed, an inventory depletion calculation is required to achieve peak reactivity. A future safety case will need to meet ONR expectations regarding burn-up credit and address the relevant questions outlined in ONR regulatory research (ref. [90]).

152. The RP uses the standard US nuclear code MCNP 6.2 in their analysis along with an ENDF/B-VII nuclear data library and a criticality safety criterion of 0.95. Standard sensitivity, uncertainty methodology, and techniques described in NUREG/CR-6698 (ref. [91]) will be used to choose appropriate critical benchmarks and estimate the calculational bias. A future safety case will need to consider independent crosscheck by an independent organisation in line with ONR guidance in NS-NAST-GD-097 (ref. [61]).

153. There are no plans for criticality warning systems to be installed within the BWRX-300 standard design with justification based upon US NRC Regulation 10 CFR §50.68 Criticality Accident Requirements (ref. [92]). ONR's technical assessment guide NS-TAST-GD-018 Criticality Warning Systems (ref. [58]) states that if criticality warning systems are not installed, an omission case is required. A future safety case will need to meet ONR expectations with regards to relevant guidance in NS-TAST-GD-018 (ref. [58]).

154. The RP highlighted the various accident conditions scenarios that will be considered in their future criticality safety analysis (ref. [93]). Such as:

- Dropped and damaged fuel bundle
- Abnormal position of a fuel assembly outside of the fuel storage rack
- Dropped bundle on rack
- Rack sliding due to a seismic event, which causes water gaps between rack to close
- Loss of fuel pool cooling
- Fuel pool heat-up

155. In line with ONR SAP ECR.2 (ref. [12]), a future criticality safety case will need to employ the double contingency principle.

156. The RP also stated that the BWRX only has two devices for moving fuel so no more than two bundles can be outside of a designated storage area at one time.

157. The spent fuel pool storage racks use borated stainless steel as neutron absorbers to maintain subcriticality. The spent fuel pool will not use boronated water.

158. ONR SAP ECR.1 (ref. [12]) states that 'the principal means of passive engineering control of criticality should be geometrical constraint'; this is supported by IAEA guidance SSG-63 (ref. [65]). The RP has claimed that due to the design of BWRX-300, the additional cost of constructing the spent fuel pool to maintain subcriticality using geometric constraint alone would be significant. They also state that the additional risk of using absorbers is minimal. It is therefore implied that the cost to mitigate this risk would be grossly disproportionate so the risk of using absorbers to maintain subcriticality is ALARP. From a fundamental assessment perspective, there is no evidence to dispute this claim. However, a future safety case will need to provide quantitative evidence to substantiate their claim in line with the ALARP Evaluation section of PSR Chapter 27 (ref. [8]) of the BWRX-300 safety case. The RP has also put forward evidence (ref. [94]) to substantiate their claim that there will be negligible degradation of the borated material over the lifetime of the plant.

159. **In conclusion**, no fundamental issues with respect to out of core criticality for fuel handling and storage have been identified during the Step 2. A future safety case will need to provide evidence of substantiation, underpinning the criticality safety arguments.

5. Conclusions

160. This report presents the Step 2 radiological protection assessment for the GDA of the BWRX-300 design. The focus of my assessment in this step was towards the fundamental adequacy of the design and safety case. I have assessed the SSSE chapters and relevant supporting documentation provided by the RP to form my judgements. I targeted my assessment, in accordance with my assessment plan (ref. [16]), at the content of most relevance to radiological protection against the expectations of ONR's SAPs (ref. [12]), TAGs (refs. [60], [56], [59]), IRR17 regulations (ref. [62]), and other guidance which ONR regards as relevant good practice, such as IAEA standards (refs. [63], [64], [66]).

161. Based upon my assessment, I have concluded the following:

- I judge the format, structure, and content of the radiological protection aspects I assessed at Step 2 to be consistent with UK regulatory expectations and IAEA guidance. The CAE are sufficient for purposes of Step 2, however, it would be beneficial to develop more specific claims for radiological protection. At Step 2, the safety case currently lacks sufficient evidence to support the safety claims and arguments in PSR Chapter 12; this will need to be addressed in a future safety case submission.

- I have not identified any fundamental shortfalls that would prevent future compliance with IRR17. I consider the BWRX-300 conceptual design to be capable of meeting IRR17 requirements in the future; this is subject to completion of further work identified in the FAP.

- It is evident that OPEX and international guidance has been used to inform radiological protection objectives and design requirements; and that the RP has established a suitable process for assessing design changes and improvements to reduce exposures to ALARP as the design progresses.

- I judge that the approach for the dose assessment at conceptual design phase is consistent with UK and international guidance. A future safety case will need to provide sufficiently detailed dose assessments and justification that the individual doses are acceptable and reduced to ALARP.

- I judge that radiological source terms for the BWRX-300 are sufficiently developed and conservatively derived for the purposes of design development (e.g. shielding design). I consider the BWRX-300 design choices to minimise source terms to be consistent with UK and international guidance. The RP recognises the need to develop a full suite of substantiated source terms to underpin shielding analysis and dose assessments, as captured in the FAP.

- The RP has used OPEX to inform the shielding design requirements, alongside industry recognised codes and approaches to assess shielding provisions in line with UK guidance. I judge this to be sufficient for Step 2 assessment; however, a future safety case will need to demonstrate with evidence that shielding provisions have been substantiated and where appropriate optimised as the design progresses.

- Based on the RP's use of OPEX and proposed approaches, it is my opinion that the BWRX-300 will be designed to modern standards and capable of being operated within regulatory dose limits outlined in IRR17 and below the BSLs for Targets 1, 2, and 3. A future safety case will need to provide sufficiently detailed dose assessments to demonstrate compliance with all dose limits outlined in IRR17 and further justification that doses to workers and the public have been reduced to ALARP.

- Finally, no fundamental issues with respect to out of core criticality have been identified during the Step 2. A future safety case will need to provide evidence of substantiation underpinning the criticality safety arguments.

162. Overall, based on my assessment, and subject to the provision and assessment of suitable and sufficient supporting evidence in either a future Step 3 GDA or during site specific activities, I have not identified any fundamental safety shortfalls that could prevent ONR permissioning the construction of a power station based on the generic BWRX-300 design.

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Appendix 1 – Relevant SAPs considered during the assessment.

SAP reference	SAP title
RP.1	Normal operation (Planned Exposure Situations)
RP.3	Designated areas
RP.6	Shielding
RP.7	Hierarchy of control measures
NT.1	Assessment against targets (Targets 1, 2 & 3)
Target 1	Normal operation – any person on the site
Target 2	Normal operation – any group on the site
Target 3	Normal operation – any person off the site
ECR.1	Safety measures
ECR.2	Double contingency approach