Office for Nuclear Regulation

New Nuclear Reactors: Generic Design Assessment

Summary of the GDA Assessment of Hitachi-GE Nuclear Energy, Ltd.'s UK ABWR Nuclear Reactor and ONR's Decision to Issue a Design Acceptance Confirmation

December 2017

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Foreword

I am delighted to be able to present this summary report of the Generic Design Assessment (GDA) of the GE Hitachi Nuclear Energy Ltd. UK Advanced Boiling Water Reactor (UK ABWR), which sets out the basis for our decision to issue a Design Acceptance Confirmation (DAC) for this reactor design.

The GDA process allows the regulators to get involved with designers at an early stage. By assessing the design early, potential issues that could challenge the safety or security of the design can be identified and highlighted, so that they can be addressed by the Requesting Party that submitted the design for assessment before commitments are made to construct the reactors.

Through the GDA process, conducted jointly with the Environment Agency and Natural Resources Wales, we have completed our assessment of the UK ABWR nuclear reactor and I am satisfied that Hitachi-GE has demonstrated that its UK ABWR reactor design is suitable for construction and operation on a nuclear licensed site in the UK, subject to:

- Incorporation into the safety case and security plan of site specific factors that may affect safety and/or security; and
- Resolution of assessment findings and consideration of minor shortfalls, identified as part of GDA, during the subsequent development of the design to be deployed to site.

By its nature, the GDA process cannot consider all aspects of the detailed design as local site conditions need to be considered. We will continue our work to ensure that site specific factors are taken into account and that our GDA assessment findings are satisfactorily addressed during the development of the site specific design.

The issuing of the Design Acceptance Confirmation is the culmination of four years of regulatory scrutiny of the generic reactor design by my team of specialist inspectors, and is a significant step towards the construction of the UK ABWR in the UK.

We have learned from our work on the UK ABWR project and this learning will inform potential improvements to the GDA process for any future reactor designs, as we seek to continuously improve our own regulation of the industry. Me and my team at ONR remain committed to delivering effective and efficient regulation and influencing improvements in nuclear safety and security across the industry, while holding it to account on behalf of the public.

Mr M Foy
Chief Nuclear Inspector

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Introduction

This is ONR's final report on the GDA of the UK ABWR and marks the completion of the GDA process for this reactor design. The report provides a summary of ONR's work and assessments, but does not include detailed information on the GDA process or its background and development, as this is documented in guidance already published on our website (Refs. 1-3).

In 2013, the UK Government requested that ONR, jointly with the Environment Agency and Natural Resources Wales, undertake the Generic Design Assessment of the Hitachi-GE UK ABWR reactor design for construction in Great Britain (GB).

The final step of the ONR element of the UK ABWR GDA process (Step 4 - Detailed design, safety and security assessment) was completed in early December 2017.

For ONR to be able to provide a DAC, ONR must have completed a 'meaningful assessment', whereby ONR has:

- received sufficient information (submissions that cover the scope and depth necessary for ONR to carry out its assessments) on the generic design in the safety and security submissions to allow assessment in all relevant technical topic areas; and
- completed a sufficiently thorough and detailed assessment of that information. This means that ONR has looked in detail at the submissions and judged them against the safety assessment principles (SAPs), including the need to demonstrate that risks are reduced, or are capable of being reduced, as low as reasonably practicable (ALARP), and against appropriate nuclear security standards.

ONR has now completed its assessment, concluding with our decision to issue a Design Acceptance Confirmation (DAC) to Hitachi-GE Nuclear Energy Ltd.'s (Hitachi-GE) for the UK ABWR.

The issue of a DAC is, in effect, an agreement with the Requesting Party (RP), Hitachi-GE in this case, that ONR would not intend to re-assess generic matters related to the UK ABWR design that have already been accepted as meeting UK regulatory requirements through the GDA process. This is subject to the close out of Assessment Findings (AFs) identified during the GDA process

However, it is noted there are circumstances where targeted re-assessment in specific areas may be necessary in the interests of safety or security (e.g. if the reactor is to be built at a site whose characteristics are not bounded by the generic site characteristics assumed during GDA, if the reactor design is subsequently and materially modified in a way that could affect safety or security, or in the event that new information becomes available that could not reasonably have been considered during the GDA process).

The issue of a DAC reflects ONR's confidence that the generic design is capable of being built and operated in Great Britain in a manner that would secure our safety and security expectations and standards, and means that all GDA 'Regulatory Issues' and 'Regulatory Observations' raised by ONR were satisfactorily resolved during the GDA process.

This report provides an overview of the work undertaken during GDA to reach this conclusion, and is underpinned by a number of detailed topic specific Assessment Reports (ARs) covering a comprehensive range of technical areas that are important for demonstrating the safety and security of the UK ABWR design. These have been published and are referenced towards the back of this report (Ref. 27-50).

ONR has also published updates and other information on its progress through the UK ABWR GDA assessment process (Ref. 4).

The ARs (and this report) provide a more detailed description of ONR's assessment of the UK ABWR design, and outline the basis for our decision to issue a DAC in this case. They also set out residual matters in the form of 'Assessment Findings' (AF) or 'Minor Shortfalls' (MSs) (that are best, or can only be, addressed at a later stage of the design, construction or commissioning of this reactor).

It should be noted that completion of the GDA process represents the first stage in the regulatory process for the construction of a nuclear reactor, and does not convey regulatory permission to commence its construction. GDA is necessarily limited in scope to providing clarity on the suitability of the generic design for construction in Great Britain.

Before construction of a reactor can commence, further development of the design and safety case are required to take account of site specific parameters, matters of site layout, detailed equipment specification, and consideration of any operational factors that need to be resolved.

Management of GDA Assessment

2.1 Assessment Strategy

The GDA of the UK ABWR commenced in 2013 following a claims-arguments-evidence hierarchy. Major technical interactions started in Step 2 with an examination of the main claims made by Hitachi-GE for the UK ABWR. In Step 3, the arguments which underpin those claims were examined.

Step 4 has been the longest and most detailed phase of the assessment, looking in depth at safety and security evidence which supports the fundamental claims and arguments, and considering how the totality of the information presented to ONR has been brought together by Hitachi-GE to demonstrate that the UK ABWR can be built and operated safely and securely in GB.

ONR developed detailed assessment plans for each technical area, in advance of commencing the GDA Step 4 assessment, to ensure that our assessments were proportionate, targeted, and would generate the evidence necessary to determine whether the issue of a DAC was or was not justified for the UK ABWR design.

This ensured that our work was both proportionate for the generic level design phases of this reactor (the pre-construction safety report phase), and that it was targeted at those areas of greatest risk significance.

Whilst ONR ensures that all assessments undertaken are of sufficient depth to allow informed safety and security judgements to be made on the adequacy of the UK ABWR design, it is impractical (and would be disproportionate) for it to assess every aspect of every safety submission.

Consequently, the UK ABWR GDA process has been undertaken in a manner consistent with ONR's longstanding practice of proportionate sampling of submissions, informed by a range of criteria including risk significance, confidence in submission quality, and novelty of the proposed approach to securing safety or security. Notwithstanding this, the process is designed to ensure that the assessment is a coherent, complete and logical account of the safety/security claims, arguments and evidence made, sufficient to justify ONR's decision to issue a DAC or otherwise.

2.2 Programme of Work Undertaken

The GDA process is, as would be expected, resource intensive.

During the course of the UK ABWR GDA, ONR has committed just in excess of 20,000 inspector days of effort and has utilised more that £9.5m of technical support contractor effort to provide supplementary expert support to our specialist inspectors. As a consequence, the UK ABWR GDA required financial commitment from Hitachi-GE of approximately £34m for ONR regulatory costs.

To deliver our assessment of the UK ABWR design, and to agree any necessary improvements to submissions throughout the GDA process, our inspectors and technical support contractors held more than 800 technical meetings with Hitachi-GE. The majority of these were held in Great Britain although some were held in Japan when it was more cost effective or more practical to do so.

During the course of the UK ABWR GDA process, Hitachi-GE submitted more than 6000 technical documents.

In assessing such submission, the GDA process enables ONR to identify the following:

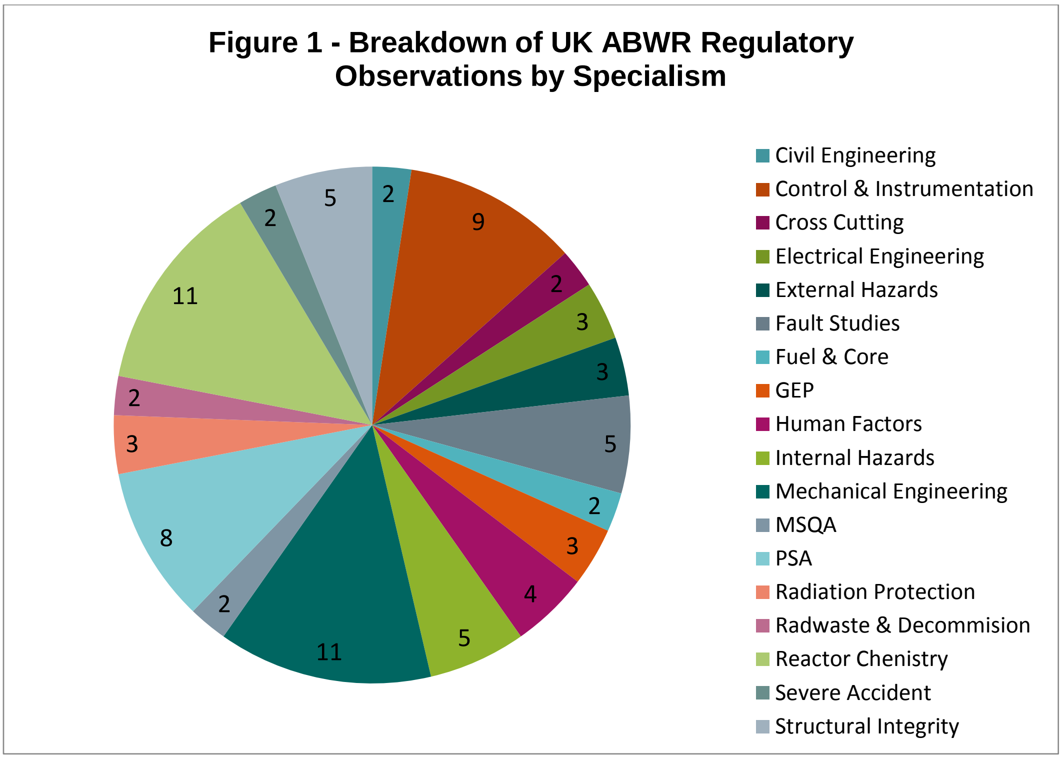
- Regulatory Issues (RIs) – are raised when ONR identifies a serious regulatory shortfall which has the potential to prevent provision of a DAC, and requires action and new work by the Requesting Party (RP) for it to be resolved. Each RI can have several associated Actions;

- Regulatory Observations (ROs) – are raised when ONR identifies a potential regulatory shortfall which requires action and new work by the Requesting Party for it to be resolved. Each RO can have several associated Actions; and

- Regulatory Queries (RQ) – RQs are requests by ONR for clarification and additional information and are not necessarily indicative of any perceived shortfall.

During the assessment of the UK ABWR submissions, ONR identified two RIs (one raised jointly by ONR and the environmental regulators relating to the need for Hitachi-GE to define the radiological source term associated with the UK ABWR during normal operations, and the other relating to the need for suitable and sufficient probabilistic safety analysis (PSA) to be conducted to support ONR's assessment of the UK ABWR design). Both were raised in 2015, and closed in 2016 and 2017 respectively. The detailed descriptions of these RIs, their resolution plans and the assessments of the responses to enable close out are published at Reference 6.

ONR and the environmental regulators also raised 82 ROs during the process, with the breakdown by specialism as per Figure 1. All 82 of these ROs were closed out by November 2017, with the detailed ROs, Resolution Plans, and closure letters for those raised by ONR published at Reference 7. No ROs were raised during the security GDA Step 4 assessment.



(NB. GEP relates to ROs raised by the environmental regulators)

ONR and the environmental regulators also submitted 1519 RQs, all of which were responded to by Hitachi-GE.

Whilst the closure period of the UK ABWR GDA was intensive, the successful addressing of both RIs and ROs by Hitachi-GE, to the satisfaction of ONR and the environmental regulators, has allowed the GDA process to complete to time and quality.

2.3 Project Governance

ONR applied rigorous project management and governance disciplines to the UK ABWR GDA project, with the project being delivered to a pre-defined plan and budget, with progress and expenditure controlled tightly throughout.

Multiple layers of governance oversight were applied to the project to ensure its rigour, objectivity, and independence from inappropriate influence.

Each of the technical areas was allocated to one of three Delivery Management Groups (Engineering, Science and Safety Analysis), who applied technical governance to the assessment work being undertaken. Cost and schedule was monitored by an experienced programme manager.

A Sub-Division Board and Regulatory Review Panel (chaired by ONR’s Head of ABWR regulation) provided a further layer of governance to ensure that ONR’s technical assessments and decisions were robust, and that cost, schedule and project risks were appropriately managed.

Assessment Reports were also subject to peer review, before approval by the relevant ONR specialism Professional Leads (independent of the project), with co-operative working and consultation with environmental regulators on matters of mutual interest.

Additionally, the regulatory assessments, related decisions, schedule and costs were scrutinised by the New Reactors Divisional Board (chaired by the responsible Deputy Chief Inspector), with regular reporting to ONR's senior level Regulatory Management Team (chaired by ONR's Chief Nuclear Inspector).

Progress reports were made to ONR's Executive Management Team and Board.

In addition, an ONR 'in project' assurance review was conducted during GDA Step 4, and an independent ONR assurance review conducted prior to the final DAC decision.

Records of this governance have been retained, and these reviews confirm that the UK ABWR GDA process was conducted in accordance with relevant ONR processes, standards, and guidance, and that the regulatory outcomes have been appropriately challenged, scrutinised and endorsed.

The final regulatory decision to issue a DAC was also subject to robust governance in the form of sub-divisional endorsement, divisional endorsement, a regulatory review and challenge panel and, ultimately, endorsement by ONR's Chief Nuclear Inspector.

2.4 The assessment standards and demonstration of "as low as reasonably practicable" (ALARP Principle)

ONR's 'New Nuclear Reactors: Generic Design Assessment Guidance to Requesting Parties' (Ref. 14) notes that, if ONR is fully content with the generic safety and security aspects of a proposed reactor design, then it would provide the Requesting Party with a DAC. This would mark the end of the GDA process.

It also notes that provision of a DAC means that, in ONR's opinion and on a site bounded by the generic site envelope, the generic reactor design could be built and operated in Great Britain, in a way that is acceptably safe and secure (subject to site specific assessment and licensing).

To reach this position, ONR must make a risk-informed decision during GDA on the acceptability of the safety of the proposed reactor design. ONR does this by assessing the nature and levels of risk against a general legal duty that risks be reduced 'so far as is reasonably practicable' (SFAIRP) [N.B. the terminology 'as low as reasonably practicable' (ALARP) is commonly used and is effectively synonymous with 'SFAIRP].

ONR's risk-based framework for making safety related regulatory decisions is set out in 'Risk Informed Regulatory Decision Making' (Ref. 15), which explains that, whilst the risk informed framework is used in making regulatory decisions on safety matters during GDA, due to differences in legislation, an alternative approach is used to make decisions on security matters.

To facilitate ONR's decision making on safety matters, an RP is required to provide an adequate safety case (a compilation of documentation that demonstrates the acceptability of the safety of the reactor design, and which demonstrates that risks have been reduced ALARP) to ONR.

Section 7.2 of Reference 15 lists important factors that ONR takes into account in its' decision to issue a DAC in relation to a new nuclear reactor design and notes that, to secure the demonstration that the level of risk has been reduced to ALARP, four main areas are to be addressed. These are:

- That ONR reaches a clear conclusion that any reasonably practicable improvements to the design identified during GDA have been incorporated (and therefore the level of risk has been reduced to ALARP);

- Relevant good practice has been incorporated into the design where reasonably practicable, including comparisons with national and international standards;

- That requesting parties present an acceptable rationale for the evolution of the proposed design from its forerunners (having examined the reasoning for adopting or rejecting design features to create an optimally safe design); and

- That risk assessment is used to identify potential engineering and/or operational improvements, in addition to confirming the numerical level of safety achieved (as set out in Ref. 12).

'Relevant good practice' (Ref. 15) is the starting point in assessing a Requesting Party's generic safety case in order to demonstrate that risks have been reduced ALARP. However, the strict test in the GB regulatory framework, applied in GDA to a submitted safety case and design, as to whether additional risk reduction measures should be adopted is the principle of 'gross disproportion' (i.e. a judgement as to whether the sacrifice (in money, time, trouble or otherwise termed costs) is or is not grossly disproportionate to the reduction in risk achieved).

Sources of relevant good practice include ONR's 'Safety Assessment Principles for Nuclear Facilities' (SAPs, Ref. 16), ONR's Technical Assessment Guides (TAGs, Ref. 17), ONR's Technical Inspection Guides (TIGs, Ref. 18), guidance and standards issued by the International Atomic Energy Agency (IAEA) and the Western European Nuclear Regulators' Association (WENRA), and engineering codes produced by standard making organisations (e.g. American Society of Mechanical Engineers, or the International Electrotechnical Commission).

The SAPs provide the regulatory principles against which the UK ABWR generic safety case has been judged and are therefore the primary basis for the nuclear safety assessments undertaken to support ONR's DAC decision. They are also the main method by which we seek to implement IAEA and WENRA standards in a GB legal context. The latest version of the SAPs (Ref. 16) was benchmarked against the extant IAEA guidance and standards in 2014, with changes made as necessary. ONR's TAGs, which provide further guidance to ONR specialists on interpreting the SAPs, explicitly identify additional IAEA and WENRA guidance as examples of relevant good practice as appropriate.

The individual Assessment Reports (Refs. 27 to 50) detail the specific standards considered by ONR in the assessment of the UK ABWR safety case in each of the different topic areas.

2.5 Joint working with Environment Agency and Natural Resources Wales, using the Joint Programme Office

Whilst ONR, and the Environment Agency and Natural Resources Wales (the environmental regulators) have separate legal roles and responsibilities, the GDA process is designed to ensure that regulators work in a coordinated manner to ensure a compatible approach across their respective regulatory interests as required by the Regulators Code (Ref. 11).

To ensure such working, whilst recognising the distinct regulatory roles of each regulator, the UK ABWR GDA project was administered by a single Joint Programme Office (JPO), and by the adoption of similar processes.

Whilst there are several areas of common interest, the most obvious example of where it has been beneficial for ONR and the environmental regulators to work together is on radioactive waste management, where both parties have complementary regulatory interests.

However, at the end of the process (and reflecting their distinct remits), ONR and the environmental regulators produce separate reports to explain, respectively, the justifications for awarding a DAC and Statement of Design Acceptability (SoDA).

As a consequence, this report relates specifically to ONR considerations in relation to the appropriateness or otherwise of the issue of a DAC.

2.6 Technical Support Contractors

As outlined in section 2.2 of this report, in common with many other national and international regulatory bodies, there are instances where it is most efficient for ONR to procure expert support and advice from Technical Support Contractors (TSCs).

Typically, TSCs are only used in cases where ONR:

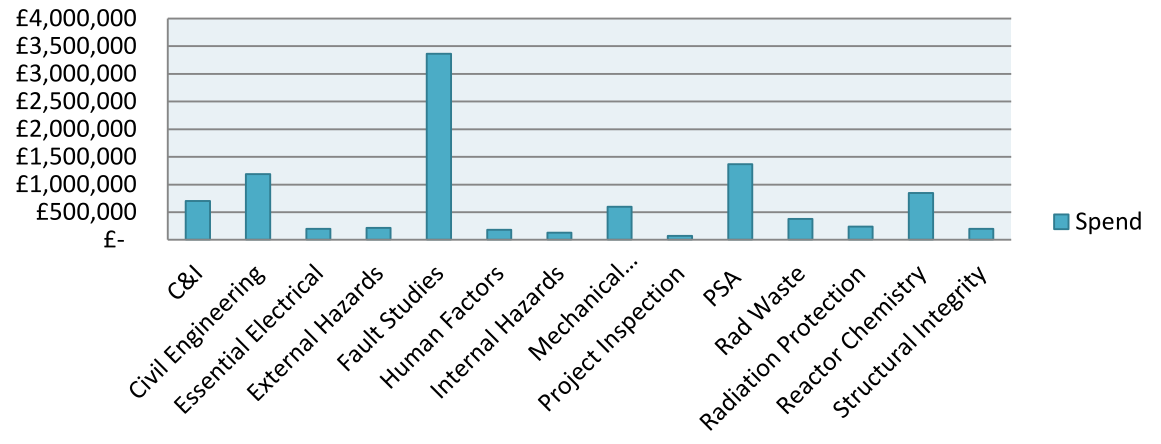
- Does not have sufficient capacity and/or capability in-house to deliver work within a required time window; or
- Would not wish to retain the capacity and/or capability in-house (e.g. for very specialised capabilities that are used only sporadically or for specific time periods).

ONR recognises that the TSC supply chain in the UK is limited and that some of its contractors may also work elsewhere in the nuclear industry. ONR applies contracting processes that require robust arrangements and controls to be put into place to ensure that conflicts of interests do not occur.

In addition, wherever ONR does decide that it needs to contract TSCs, the TSCs operate under a clear work specification defined by ONR, and under the direct supervision and control of an experienced ONR inspector. Ultimately, this ensures that ONR makes any regulatory decisions that may arise from the work of the TSC, retains sole responsibility for the discharge of its regulatory functions, and acts as an 'intelligent customer' for the outputs of its TSCs.

Where TSCs have been used, the relevant AR indicates the nature of their contribution. During the UK ABWR GDA process, ONR raised 45 technical support contracts with a combined value of £9.5m (see Figure 2).

Figure 2 - UK ABWR TSC Spend by Discipline: 2014 - date



2.7 Openness and transparency

ONR is committed to the principle of openness and transparency in terms of its activities, and publishes its decisions and underpinning justifications so that our stakeholders can see the basis of our regulatory decisions.

The GDA programme, since its inception, has published periodic progress reports, assessment reports, and summary reports to help to build public confidence in the work that we do. We also require that GDA requesting parties host a public comments process and publish key submissions made to ONR. ONR notes that some information may be redacted due to nuclear security related restrictions.

In 2015, ONR participated, along with the Environment Agency and Natural Resources Wales, in a project run by ‘Sciencewise’. This project aim was to identify how to better understand the needs of the public in relation to engagement in the GDA process for new nuclear reactor designs, by undertaking a dialogue with members of the public. A report on this work is published at reference 12.

In the case of the UK ABWR GDA process, ONR has published:

- reports produced in relation to the UK ABWR during GDA steps 2 and 3 (Ref. 4);
- the RIs and ROs raised during GDA, along with their resolution plans and close out assessments or letter (Refs. 6 and 7); and
- reports produced by ONR during step 4 of the GDA process (Refs. 27-50).

2.8 Working with overseas regulators

ONR is committed to working with equivalent international regulators, both bilaterally and multi-nationally, and has engaged with a number of other international regulators throughout the GDA process.

Specifically, ONR has engaged through its membership of the (Organisation for Economic Co-operation and Development (OECD) facilitated) Multinational Design Evaluation Programme (MDEP); ABWR working group. This group has representation from the nuclear safety authorities of Japan, Sweden, USA, and the UK and had initial national representation from Finland (until the potential operator in Finland took the decision not to build an ABWR).

This is a multinational initiative which aims to develop innovative approaches to leveraging resources, knowledge and understanding of new reactor power plant designs. This helps to promote consistent nuclear safety assessment standards across participating countries and has informed relevant national authorities on the USA Design Certification Renewal for the ABWR, restart reviews of the Japanese Kashiwasaki-Kariwa ABWR Units 6 and 7, the UK ABWR, and Sweden's considerable experience in Boiling Water Reactors (BWRs).

A range of aspects of ABWR design have been discussed via the MDEP route, including:

- A shared position on the learning for ABWRs arising from the Fukushima accident;
- The sharing of operational experience from the USA and Europe;
- The agreement of international expectations regarding the ABWR response to severe accidents;
- A review of significant differences between operating ABWR reactors and new reactor designs etc.

The work ONR has conducted with overseas regulators has made a helpful contribution to its assessment of the UK ABWR design.

3 UK ABWR GDA safety and security submissions

3.1 Overview of UK ABWR GDA safety and security submissions

The scope of the UK ABWR GDA, and therefore the extent and limitations of the DAC decision made by ONR, is defined by four key documents produced by Hitachi-GE:

- Generic Pre-Construction Safety Report (PCSR);
- Conceptual Security Arrangements;
- GDA Design Reference; and
- Master Document Submission List.

The Generic PCSR (Ref. 13) is the main submission supplied by Hitachi-GE to allow ONR to reach its regulatory judgements. It follows a claims-arguments-evidence approach consistent with ONR's guidance (Ref. 14) to show that the risks from the UK ABWR have been reduced SFAIRP. The declared top level claim it sets out to demonstrate is that "a UK ABWR constructed on a generic site within GB, meets all safety targets for the public, workers and the environment, and satisfies the principle that all risks are as low as reasonably practicable (ALARP) for all operating and fault conditions".

The Generic PCSR is structured in five parts, each of which is made up of a number of chapters, as shown in Figure 3. These chapters make additional, lower level claims for specific topics and aspects of the design, in support of the declared top level claim. These are justified by further arguments (or 'reasoning') and 'evidenced' by real data, experiment or other suitable means.

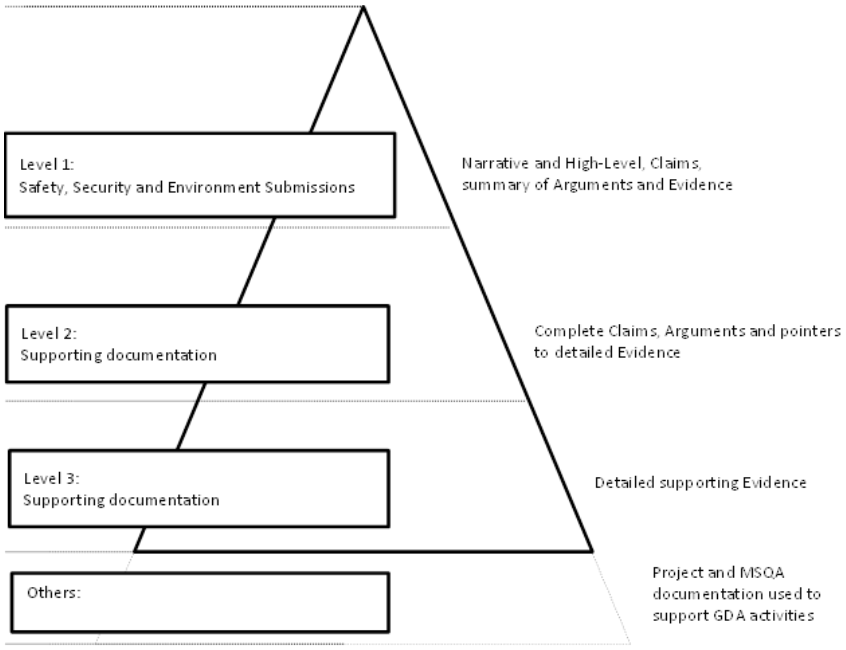
Figure 3 UK ABWR Generic PCSR Structure

Part-I: General Issues	Part-II: Technical Systems	Part-III: Systems and Processes to Support Operation, and Engineering Substatiation	Part-IV: Assesswment	Part-V: Framework of Dealing with Issues Specific to Plant Life Phase
1. Introduction	9. General Description of the Unit (Facility)	18. Radioactive Waste Management	24. Design Basis Analysis	29. Commissioning
2. Generic Site Envelope	10. Civil Works and Structures	19. Fuel Storage and Handling	25. Probabilistic Safety Assessment	30. Operation
3. Site Characteristics (Not Included in Generic PCSR)	11. Reactor Core	20. Radiation Protection	26. Beyond Design Basis and Severe Accident Analysis	31. Decommissioning
4. Safety Management throughout Plant Lifecycle	12. Reactor Coolant Systems, Reactivity Control Systems and Associated Systems	21. Human-Machine Interface	27. Human Factors	32. Spent Fuel Interim Storage
5. General Design Aspects	13. Engineered Safety Features	22. Emergency Preparedness	28. ALARP Evaluation	
6. External Hazards	14. Control and Instrumentation	23. Reactor Chemistry		
7. Internal Hazards	15. Electrical Power Supplies			
8. Structural Integrity	16. Auxiliary Systems			
	17. Steam and Power Conversion Systems			

While the Generic PCSR is important, it forms only a part of the overall safety documentation for the UK ABWR considered by ONR during the course of GDA. Sitting beneath the generic PCSR is a series of more detailed technical analysis and engineering reports which have been submitted to ONR for assessment. These, in turn, have many supporting references which provide more detailed design information, evaluations, and analysis to support claims and arguments made in the higher level reports. Figure 4 shows Hitachi-GE's hierarchy of three levels of Generic PCSR documentation.

For nuclear security, Hitachi-GE submitted 'Conceptual Security Arrangements', which detail those areas of plant identified as requiring protection, and define generic security arrangements to ensure prevention of theft or sabotage of nuclear materials or equipment. This allows ONR to assess it against its nuclear security 'National Objectives, Requirements and Model Standards'.

Figure 4 Hierarchy of Generic PCSR Documentation



The Master Document Submissions List (Ref. 22) records all the documentation submitted by Hitachi-GE (at all levels, including the generic PCSR), during the course of GDA, to substantiate its claims-arguments-evidence approach to demonstrating the adequacy of the UK ABWR with respect to safety (and security), and any additional information / evidence requested by ONR during the course of the GDA process. This is important as it establishes, unambiguously, the suite of documentation that represents the design assessed during GDA, being the 'baseline' design against which a DAC decision is made.

Two features of the GDA process are that it:

- allows ONR visibility of the reactor design at an early stage during which it has maximum influence in the interests of safety and security (as design changes required to address regulatory expectations are more readily implemented at an early design stage rather than when construction has begun, or expensive plant items have been manufactured); and

- relates to a generic reactor design (which does not reflect any specific site on which it may subsequently be built, but does consider generic site characteristics intended to bound potential UK sites).

This means that, at the start of the GDA process, there is not a fully-developed design for the proposed reactor that would be sufficient to allow construction. It is anticipated that refinements to the generic design will be made, as appropriate, during the course of GDA. It is also to be expected that, by the end of the GDA process, there will be a significant amount of more detailed and site specific design work to be undertaken before the design would be sufficiently developed to allow the construction of the reactor.

Hitachi-GE defined a baseline for the reference design to be considered during GDA in 2014 based on a "Japanese Reference Plant" (Kashiwazaki-Kariwa Nuclear Power Station, Units 6 and Unit 7 (KK-6/7)) augmented with a number of minor modifications introduced into subsequent Japanese ABWR designs. This baseline was formalised in an initial issue of a GDA Design Reference report in 2015. This report was maintained as a 'live' document through to the end of GDA, with any design changes identified by Hitachi-GE as being necessary to meet its safety case and security claims being controlled and introduced through a strict process.

Reference 21 is the final version of the UK ABWR GDA Design Reference report. It establishes the design of the UK ABWR that the generic PCSR (and its supporting references) is setting out to demonstrate safety for, and is therefore what ONR's GDA regulatory judgements are against.

3.2 Scope of GDA

ONR requires sufficient generic design work to have been undertaken to enable it to complete the GDA process meaningfully. However, given that the GDA process is undertaken at an early stage and that it only considers the generic design, there are a range of other important aspects of the development of the design and safety case that will need to be addressed before a plant can be constructed and operated. These are accepted by ONR as necessarily falling outside of the scope of GDA.

For example, significant evidence and associated confirmatory analysis to support the safety case cannot be gathered until the structures, systems and components (SSCs) have undergone final detailed design by a manufacturer/ supplier, or have been manufactured and are in the process of being tested or commissioned. ONR recognises that this is unavoidable.

Since the choice of supplier and choices relating to construction and commissioning, are matters for any future licensee (rather than the RP), this level of information is excluded from the scope of GDA.

However, during GDA, ONR expects the RP to provide adequate arrangements to demonstrate that the safety claims and assumptions can be realised within the design that is finally constructed, which ONR is satisfied that Hitachi-GE has done.

In addition, during GDA, ONR expects that the safety of the generic reactor will be demonstrated within the context of generic (bounding) site characteristics, including:

- the density and distribution of an assumed local population;
- external hazards; and
- grid connections.

The characteristics adopted in the generic site envelope should, so far as is possible, bound the characteristics of known potential nuclear reactor construction sites in Great Britain in order that reactors of the proposed design could potentially be built at these locations.

However, determining the characteristics of any specific site in Great Britain, and demonstrating the robustness of a reactor design against those characteristics, is not part of the GDA process. Consequently, the future operator will need to demonstrate the suitability of a specific site and the acceptability of the impact of the specific characteristics of the site on the reactor safety case.

The generic nature of the design considered during the GDA process, and the need for further detailed design and other considerations to be made by the potential operator (as above), means that detailed consideration of the following aspects of the design are outwith the scope of GDA:

- detailed equipment and plan specification;
- aspects of materials specification;
- operational resourcing levels;
- operating technical specifications;
- maintenance schedule;
- procedures (normal operation, emergency, waste management, accident management);
- training programmes;
- emergency preparedness arrangements;
- operating limits;
- radiation protection arrangements for operators;
- plant lifetime records;
- commissioning requirements and records;
- decommissioning requirements and procedures, etc.

Although ONR accepts and is content that the scope of GDA is unavoidably limited by such factors, it has committed significant regulatory attention to ensuring that Hitachi-GE has clearly identified all relevant assumptions, constraints and requirements established through the generic PCSR that will need to be taken into account by a future licensee.

Hitachi-GE has defined the scope of the UK ABWR GDA (e.g. in terms of plant, facilities, buildings and operations) in Chapter 1 of the PCSR (Ref. 19), and has defined the safety significant structures (the design of which is predominately independent of site specific conditions) notably:

- The Reactor Building;
- The Reinforced Concrete Containment Vessel (RCCV);
- The Control Building;
- The Heat Exchanger Building;
- The Turbine Building;
- The Radioactive Waste Building;
- The Main Discharge Stack etc.

In such cases, the Hitachi-GE approach has been to provide sufficient design and safety case information to facilitate a full assessment as appropriate to GDA.

For some other facilities (and their operations), the submissions have, understandably, been less detailed in nature, for example:

- The spent fuel interim store;
- The service building;
- The internal design of the backup building;
- The solid radioactive waste system; and
- The tunnels running between various buildings.

Hitachi-GE has excluded the design of the sea-water intakes from the scope of GDA.

ONR accepts and is content that certain limitations in the scope of the UK ABWR GDA are unavoidable. However, in cases where detailed considerations could not be made during GDA, ONR will revisit the relevant aspects of the design and safety case, in order to satisfy itself that GB safety and security standards will be met, at an appropriate later stage.

4 Overview of the UK ABWR

4.1. Background

Hitachi-GE provides further information and a description of the UK ABWR design on its website (Ref. 13).

The UK ABWR is a boiling water reactor (BWR), which has two fundamental differences from Pressurised Water Reactor (PWR) technology, as follows:

- Bulk boiling of water occurs in the reactor core; and
- Steam produced from boiling in the reactor core is sent directly to the steam turbine that is used to produce electricity.

The principles of BWR technology were established in the 1950s with the first commercial BWRs coming into operation in the US in the 1960s.

The designs of commercial BWRs developed and evolved over time, leading to improvements and simplifications to the design. This led to the subsequent ABWR design, which is the basis for the UK ABWR discussed in this report.

ABWR development began in 1978, and was adopted for the construction of KK-6/7 in Japan. These units were supplied under a joint venture between General Electric Company and Toshiba Co. Ltd. and commenced commercial operations in 1996 and 1997 respectively.

In 1987, the U.S. Nuclear Regulatory Commission (US NRC) initiated a technical review of the ABWR under its Standard Design Certification programme, making the decision to certify the design in 1997.

Following on from the KK-6/7 projects, further ABWR construction projects were undertaken in Japan, including Hamaoka Unit 5 and Shika Unit 2.

At present, Hitachi-GE has two further ABWRs in the construction phase (Shimane Unit 3 and Ohma Unit 1). These will be the fifth and sixth ABWRs to be constructed in Japan.

4.2 Description

The UK ABWR (assessed during this GDA and defined by the Design Reference report, Ref. 21) is a further development from the ABWR designs built in Japan and certified in the US. Whilst the basic features remain the same, the UK ABWR includes design changes informed by operational experience, learning from the events at the Fukushima Dai-ichi site in 2011, and informed by GB relevant good practice and regulatory expectations.

A UK ABWR unit has a thermal power output of approximately 3900 MW and gross electrical output of approximately 1350 MW. It uses demineralised water as a coolant and neutron moderator. Heat is produced by nuclear fission in the reactor core, which causes boiling of the cooling water to produce steam. This steam is used directly to drive a turbine, after which it is cooled in a condenser and converted back to water to be recirculated to the reactor core. The cooling water is maintained at a pressure of circa 7.2 MPa (absolute) such that the water boils in the core at a temperature of approximately 285°C.

The UK ABWR layout is comprised of a reactor building, a control building, a turbine building, and a range of other ancillary facilities. Whilst the principal buildings are located adjacent to each other, the precise layout of these buildings and facilities is site-dependant.

The reactor building is dominated by a Reinforced Concrete Containment Vessel (RCCV), which contains the Reactor Pressure Vessel (RPV). The RCCV is a steel lined reinforced concrete structure, cylindrical in nature, 36m tall, 29m in diameter, with 2m thick walls and a steel bolted head. This substantial reinforced concrete structure provides the pressure containment and shielding necessary for the reactor to operate safely, whilst the steel liner prevents any leakage of radioactivity.

The RCCV is divided, by the diaphragm floor and the RPV pedestal, into a drywell and a suppression chamber. The suppression chamber contains a water filled suppression pool and an air space.

In certain severe emergency conditions (e.g. a Loss of Coolant Accident), steam may be released into the drywell space of the RCCV. In a fault condition, the steam would pass through horizontal vent pipes (embedded in the RPV pedestal) to the suppression pool where it would be condensed.

The internal volume of the RCCV (i.e. both the drywell and the suppression chamber air space) is maintained in a nitrogen-inerted state when the reactor is at power. This reduces any risk presented by hydrogen generated by radiolysis during normal operations, and by reactions of the fuel cladding during a severe emergency.

The RPV is a cylindrical steel vessel that contains the core and reactor internals. It consists of a removable hemispherical top head, cylindrical shells, a bottom head, and water and steam pipework nozzles. The RPV is around 21 metres in height, 7.4 metres in diameter, with a steel wall thickness of around 17 centimetres, and is installed vertically on the pedestal inside the RCCV. The function of the RPV is to provide the primary containment for the light water coolant and any radioactive material generated in the core during reactor operation. The RPV contains the nuclear core, steam separator, steam dryer, reactor internal pumps and control rods.

The reactor core is an upright cylindrical disposition containing 872 fuel assemblies. Each fuel assembly is comprised of a square array of fuel rods, and a hollow pipe (water rod) through which water coolant flows.

Fuel assemblies sit inside Zirconium alloy channel boxes, which form the coolant flow path, and guide the insertion and withdrawal of control rods between fuel assemblies.

Each fuel rod is a Zircaloy-2 cladding tube containing Uranium Dioxide (UO_2) pellets with less than 5wt% Uranium-235 enrichment. Plugs are welded onto each end of the fuel rod, and its plenum is filled with helium gas. At the end of a fuel cycle, the spent fuel will contain radioactive fission products, which is confined within the cladding tube.

The control rods are of cruciform cross section, and are inserted between every four fuel assemblies. The control rods have the dual functions of shaping the core power distribution and controlling reactivity. The control rods enter the vessel through the bottom dome and are inserted under either electric or hydraulic power.

The UK ABWR spent fuel pool is in the reactor building, next to the reactor (and close to the dryer separator pool). It is used to store new fuel, irradiated fuel waiting to be reloaded back into the reactor, and spent fuel at the end of its useful life.

During routine reactor shutdown to allow refuelling, the top of the containment vessel, the RPV top head, the steam separator, and the steam dryer components are removed. These components are variously laid down on the reactor building operating deck and the dryer separator pool. Fuel assemblies are moved underwater between the reactor core and the spent fuel pool using the fuel handling machine, through a gate opening between the spent fuel pool and the top of the reactor.

Fuel assemblies are typically loaded into the reactor for four separate operating cycles. After this, they are stored in the spent fuel pool for several years, before being taken out of the pool and removed from the reactor building in robust shielded casks. The assumption for GDA is that these casks will be moved to a spent fuel interim store somewhere on the wider site.

4.3 Safety Systems

Any anomalies associated with the operation of the reactor are detected and actioned by a logic-based Safety System Logic and Control (SSLC) system. In the event of a total failure of the UK ABWR SSLC, safety is delivered by a diverse hard-wired protection system, which can independently detect and manage fault conditions.

The SSLC and hard-wired protection systems act by initiating a range of specific installed safety systems.

For some anomalies, it will be a priority to trip (or scram) the reactor. To do this, the protection systems activate high pressure water, stored in nitrogen charged accumulators, to force the control rods into the core. This hydraulic scram action is backed up by electrically powered insertion of the control rods.

In the event of any problems with control rod insertion, the UK ABWR has a standby liquid control system which is a second and diverse means of reactivity control by directly injecting borated water into the RPV to bring the core to, and hold it in, a sub-critical state.

During normal operations, steam generated in the reactor is transferred to the turbine facility via four main steam pipes. Each of these steam pipes has isolation valves (MISVs) arranged in pairs on either side of the containment wall to isolate the reactor core in the event of an accident. However, this would cause pressurisation of the reactor. To prevent over-pressurisation, Safety Relief Valves (SRVs) are fitted within the containment to allow the discharge of the steam into the suppression pool at the bottom of the RCCV.

Another key safety system is the Emergency Core Cooling System (ECCS), which is made up of three independent divisions each of which is capable of maintaining the water level in the core at a safe level and transitioning the reactor to cooled safe state following an accident. Each division of the ECCS has one high pressure and one low pressure water make-up system, and is connected to its own emergency diesel generator (EDG) to provide power if the connection to the grid is lost. The pumps for the high pressure systems are either electrically (motor) or steam (turbine) driven. By having such diversity of safety systems, water level can still be maintained even in the event of a problem with the EDGs or an emergency resulting in a loss of steam.

The main means of long term removal of decay heat are the low pressure portions of the three divisional ECCS (the Residual Heat Removal system (RHR)). In addition to providing the capability to inject water into the RPV, each division incorporates heat exchangers of sufficient size that each can remove sufficient heat from the suppression pool to maintain its integrity. Once suitable conditions have been reached, the heat exchangers can remove heat directly from the RPV in a closed loop system to maintain the reactor in a stable and safe state.

In response to events at Fukushima in 2011, the original ABWR design has been modified by the addition of a back-up building located at some distance from the main reactor building. This has its own power and water supplies and can open SRVs and initiate water injection into the RPV should an extreme event compromise the capability of the main safety systems within the reactor building.

In extreme scenarios, and in the unlikely event that other diverse heat removal safety systems were unavailable, the UK ABWR design incorporates design features to allow venting of the RCCV (to protect the RCCV from failing due to overpressure). This allows the suppression chamber to be vented via the plant's stack, through pipework 'hardened' to survive the conditions anticipated in an accident. The water in the suppression pool provides an effective means of removing contamination from some radioactive compounds that would be present as a result of the event.

In a post-Fukushima improvement, this capability has been enhanced by a second, filtered containment venting system (FCVS), which can further reduce the amount of radioactive iodine and long half-life fission products that might otherwise be released following a severe accident.

Both venting routes can be manually initiated by the operators from the main control room (MCR) in the event that containment pressure challenges its design value. In addition, the FCVS route includes a rupture disk which will open automatically, even if the operator fails to take action in response to high containment pressure.

5 Overview of ONR’s Assessment

During Step 4 of the GDA process, ONR has undertaken detailed assessments of Hitachi-GE’s design and safety case for the UK ABWR across 24 main technical areas.

Details of our assessments against relevant GB regulations, standards and expectations (as well as applicable international guidance and standards) are contained in individual topic area assessment reports (Refs. 27-50), and are available on ONR’s website.

However, a summary of the key conclusions in each main area are outlined below.

5.1 Probabilistic Safety Analysis (Ref. 44)

Probabilistic Safety Analysis (PSA) is an integrated and structured safety analysis technique that considers engineering and operational features in a consistent and holistic framework. It is a quantitative analysis that provides measures of the overall risk to the public that might result from a wide range of potential plant faults or failures (e.g. failure of safety related equipment to operate; the effect of human errors; or other hazards such as fires or floods).

PSA identifies, examines and evaluates complex interactions of failures (e.g. between different systems across the reactor site) to provide a systematic basis by which to identify any relative weak points in the proposed reactor design.

International good practice is the adoption of a three-tier approach to PSA, with:

- Level 1 PSA - focusing on failures that can lead to potential for core damage;
- Level 2 PSA - widening the analysis to consider the likelihood and consequences of any potential failures that might lead to loss of containment; and
- Level 3 PSA - considering risks to the public from off-site releases arising from plant failures.

During step 3 of the UK ABWR GDA process, ONR reviewed Hitachi-GE’s initial UK ABWR PSA model for internal events at power. The conclusion of that review was that further work was needed from Hitachi-GE to demonstrate that its PSA fully meet GB regulatory expectations. As a consequence, ONR raised Regulatory Issue RI-ABWR-0002 in July 2015 (section 2.2 and Reference 6 refer).

During GDA Step 4, ONR’s PSA assessment team undertook an in-depth technical assessment of the full scope Level 1, 2 and 3 PSA model developed in response to RI-ABWR-0002. As part of this assessment, ONR considered whether any differences between the reference PSA design and the final design established by Hitachi-GE at the end of GDA would have a significant impact of the predicted risk figures. Consideration was also given as to whether the PSA model is adequate to support a future licensee to demonstrate that nuclear safety risks are being managed to ALARP levels as the design process continues after GDA.

As a result, ONR has been able to conclude that the UK ABWR PSA developed in response to RI-ABWR-0002 broadly meets the expectations of ONR’s PSA TAG and is adequate to support the generic PCSR. It is satisfied that the PSA has a credible and defensible basis and allows for comparison against the numerical risk targets contained within ONR’s SAPs.

Comparison of the results of the UK ABWR PSA against SAPs Target 9 shows that the estimated risk is well below (approximately an order of magnitude) the basic safety level (BSL – a safety level that ONR expects to be met for a new facility). However, the risk remains above the basic safety objective (BSO - the level of risk below which further consideration of the safety case would not be a reasonable use of ONR resources).

This comparison of the predicted risks against the BSOs and BSLs defined in the SAPs has informed ONR's judgements on the UK ABWR design and the demonstration of ALARP, both within the PSA topic area and beyond. Specifically, in the PSA topic area, ONR's assessment team has been satisfied with how the PSA model was used to identify further ALARP improvements to be incorporated into the GDA reference design.

ONR recognises that the UK ABWR PSA model will need to be revised beyond GDA in order to reflect the final detailed design, a number of specific shortfalls identified during ONR's GDA review, as well as site specific characteristics and operational considerations that are not known at this stage. Also, as the PSA of the generic UK ABWR design is unavoidably predicated on a number of assumptions, additional substantiation of the modelling will need to be provided when detailed design information becomes available.

However, the final PSA model generated at the end of GDA is considered sufficient to inform future design developments, and provides an appropriate starting point for the ongoing PSA developments.

5.2 Fault Studies (Ref. 35)

Fault Studies is the detailed deterministic study of reactor systems, and their characteristics and modes of operation, with the aim of identifying potential faults that could lead to the release of radioactive material. It also includes the application of complex computer modelling to analyse a range of physical phenomena under steady state, transient and fault conditions (e.g. reactor core physics, thermal hydraulics, heat transfer, spent fuel pool and other facilities and activities on the generic site that have significant radiological inventories).

During GDA Step 4, ONR specialists reviewed the adequacy of the list of UK ABWR initiating events identified and modelled by Hitachi-GE, and compared the safety classification of engineered protection for faults against GB relevant good practice. ONR also undertook a detailed assessment of Hitachi-GE's transient analysis, considering the computer models and methods used, the level of conservatism included, the acceptability of the results against applicable acceptance criteria, and considered the adequacy of how this analysis has been used to support the overall UK ABWR safety case.

Through this review, ONR has been able to reach the conclusion that the generic PCSR (and supporting references) provides an adequate demonstration that the UK ABWR can be safely managed in fault conditions. Significantly, Hitachi-GE has shown that the engineered safety features included within the UK ABWR design are effective in reducing the predicted radiological consequences from fault conditions to levels which compare favourably to BSLs and BSOs defined by Target 4 in ONR's SAPs (Ref. 16). It has also provided adequate arguments, for the fault conditions analysed, to justify why the inclusion of additional measures would be grossly disproportionate for the generic UK ABWR design considered in GDA.

5.3 Severe Accidents (Ref. 48)

Conservative design, good operational practice, and robust safety measures (informed by the application of fault studies and PSA) should ensure that the frequency of fault conditions are minimised and, should they occur, that there is appropriate confidence that safety design features would ensure that the radiological consequences are small.

However, it is important that designers and operators consider the possibility that the fault studies or PSA might be incorrect, that the severity of an initiating event might have been underestimated, or a safety measure might be circumvented or fail in an unpredicted way.

In accordance with this expectation, Hitachi-GE has provided extensive submissions on the prevention and management of scenarios involving the failure of major safety systems in fault conditions and which result in extensive damage to fuel in the UK ABWR reactor core and spent fuel.

ONR's assessment of these submissions has concluded that Hitachi-GE has demonstrated that UK ABWR design provisions are effective in preventing progression of severe accident states and/or mitigating the consequences of such accidents. ONR is also satisfied that credible strategies for management of severe accidents have been identified and that these are suitable for subsequent development by a future licensee.

ONR's assessment has also looked for evidence, and has been satisfied, that the design of the UK ABWR incorporates learning from the accident at Fukushima Dai-ichi in 2011.

5.4 Nuclear Fuel and Reactor Core Design (Ref. 37)

ONR has assessed the design of the nuclear fuel and reactor core, including examination of the performance of the reactor fuel under a wide range of in-reactor and storage conditions. As part of this assessment, ONR visited the GNF facility in Wilmington, USA which produces the 'GE14' fuel assemblies proposed for the UK ABWR in order to witness the levels of manufacturing quality.

ONR is satisfied that the design of the GE14 fuel assembly and related core components reflects operational experience and reduces the operating risk as far as reasonably practical.

ONR also notes that the basis by which a future licensee will establish appropriate operating rules for the fuel has been adequately defined for the purposes of GDA.

5.5 Human Factors Assessment (Ref. 39)

Human Factors is the study of human physical and psychological capabilities and limitations and the application of that knowledge to the design of work systems.

In a nuclear context, Human Factors is concerned with the assessment of the human contribution to nuclear safety during facility design, construction, commissioning, operation, maintenance, and decommissioning.

ONR requires that a systematic analytical approach be applied to understanding the factors that affect human performance and reliability.

For GDA, ONR has focused its assessment on the following:

- The adequacy of human factors aspects of design in supporting operator performance; and

- The adequacy of Hitachi-GE's identification and substantiation of the risk important human based safety claims.

ONR concludes that Hitachi-GE has presented an adequate safety case for human factors with the identification and substantiation of human based safety claims broadly aligning with ONR's expectations for this stage of the design. In addition, Hitachi-GE has provided adequate evidence that 'human factors' considerations have been suitably integrated into the plant design.

Whilst Hitachi-GE has presented an outline design for the main control room; the exact detail of the HMI displays and controls was not available at GDA. We do not consider that the current control panel design precludes realisation of modern standards human factors design solutions.

Human factors considerations extend beyond the generic design of the reactor and will need to take into account design evolution of the reactor plant, processes and procedures for its operation. A significant amount of assessment work in this area will inevitably be carried over to the detailed design, construction, commissioning and operational phases.

However, ONR is satisfied that Hitachi-GE has adequately demonstrated that the human factors aspects of the UK ABWR generic design and associated safety case are adequate.

5.6 Radiation Protection (Ref. 45)

ONR has assessed Hitachi-GE's approach to radiation protection within the generic design, and the extent to which the proposed approaches reduce exposures to workers and the public, so far as is reasonably practicable.

Hitachi-GE has adequately demonstrated that radiation exposures from both routine and non-routine operations are below the relevant BSL, and are generally less than the relevant BSO.

In most respects, by the adoption of radiological and contamination zoning, shielding, and design for contamination control etc., Hitachi-GE has demonstrated compliance with the obligation to reduce radiation exposure so far as is reasonably practicable at this design stage. Where this is not the case, Hitachi-GE has identified further work at the detailed design stage to achieve this outcome.

Overall, ONR is satisfied that Hitachi-GE has provided an adequate demonstration of optimisation of radiological safety in relation to the generic generic reactor design.

5.7 Conventional and Fire Safety (Ref. 31&36)

ONR assessed the conventional and fire safety aspects of the generic UK ABWR design to satisfy itself that the broad expectations of the Construction (Design and Management) (CDM) Regulations 2015 were met as regards designer risk assessment aspects and the specification of the GDA envelope.

ONR is satisfied that Hitachi-GE has provided sufficient information to demonstrate its understanding and application of GB health and safety legislation (including measures, so far as is reasonably practicable, to eliminate, reduce or control foreseeable risks to the health and safety of persons carrying out or liable to be affected by construction work, including decommissioning, maintenance, and operation of the plant as a workplace).

ONR notes that Hitachi-GE is proposing what is, in GB, a novel 'open top' construction method that requires future licensee input/decision at a specific site. As a result, the future licensee will need to conduct a site-specific design review of the health and safety risks of this methodology, using the available Hitachi-GE information as a baseline.

As regards conventional fire safety, ONR has examined relevant information supplied by Hitachi-GE, and is satisfied that it demonstrates that Hitachi-GE has conducted a suitable and sufficient fire risk assessment (including of design features which deviate from British Standards). Hitachi-GE has also provided ALARP justifications to show that an equivalent standard of life safety protection from fire has been achieved where alternative fire engineering measures have been adopted.

5.8 Reactor Chemistry (Ref. 46)

ONR's chemistry assessment for the UK ABWR focused on two main themes, the:

- operating chemistry; and
- effects of chemical behaviour on the potential likelihood or consequences of faults or accidents.

Taking due account of the breadth of the relevant hazards and risks which the operating chemistry can influence, and the fundamental requirement in the GB health and safety context to reduce risks SFAIRP, Hitachi-GE proposed a "new" operating chemistry for the UK ABWR. This approach to operating chemistry has been widely adopted by the US fleet of BWRs, but has not previously been applied to any ABWRs. This was a particular focus of our chemistry assessment.

The technical justification and rationale for the chemistry control decisions taken by Hitachi-GE are prominent features in the relevant parts of the generic safety case, the basis of which ONR accepts as adequate for GDA.

Hitachi-GE has also recognised the importance of suitable materials selection given its choice of operating chemistry, to further optimise the UK ABWR design. As a consequence, Hitachi-GE made necessary and reasonably practicable improvements to the materials selected for a number of UK ABWR SSCs.

As regards the effects of chemical behaviour on the potential likelihood or consequences of faults or accidents, Hitachi-GE provided a range of arguments and evidence to support the chemistry assumptions it has used during its fault analysis. For the UK ABWR, the most notable impact of this work is the proposal to install a system to control the pH within the suppression pool during and following some potential accident scenarios, in order to further reduce the radiological consequences.

There are, as in other assessment areas, a range of aspects of the generic safety case, related to chemistry, which a future licensee will need to develop further. These include the provision of additional evidence and justifications to substantiate key decisions on the design taken by Hitachi-GE during GDA, clarification on detailed design information where this was not available during GDA, and future decisions about how the plant may be operated from a rector chemistry perspective.

Taking account of the proposed improvements and other work undertaken by Hitachi-GE, ONR is satisfied that the claims, arguments and evidence presented in the PCSR and supporting documentation for reactor chemistry provide an adequate generic safety case for the UK ABWR.

5.9 Civil Engineering (Ref. 27&28)

ONR's civil engineering assessment has considered the layout, analysis, design and nuclear safety functions of civil safety related structures, systems and components (SSCs) that are within the scope of the GDA. This assessment covered the principal buildings associated with the reactor, six main service tunnels and main tank structures, including the:

- Reactor Building (R/B);
- Spent Fuel Pool;
- Reinforced Concrete Containment Vessel (RCCV) and its internal components;
- Aircraft Impact Protection Shell;
- Control Building (C/B);
- Heat Exchanger Building (Hx/B);
- Turbine Building (T/B);
- Key service buildings;
- Reactor Cooling Water (RCW) Tunnel etc.

A key ONR focus was to examine the ability of safety related civil structures to withstand loadings due to credible external hazards as set out in the GDA generic site envelope, and internal hazards originating within the boundary of the site.

During GDA Step 4, Hitachi-GE refined its approach to seismic analysis to include the use of more accurate finite element models.

The principal safety related structures were subjected to a comprehensive analysis by Hitachi-GE, and analysis by ONR, to secure appropriate confidence in the civil and structural integrity of these facilities. Other less significant civil structures were subjected to adequate and proportionate, but more limited, assessment.

As a consequence of its assessment, ONR is satisfied that Hitachi-GE has demonstrated that, at a generic design level, UK ABWR GDA buildings, tunnels and tank foundations would fulfil their functional safety requirements over the full range of credible loadings for the lifetime of the reactor.

Hitachi-GE has also demonstrated that the external structure of the reactor building would provide sufficient protection such that it would not be breached by a direct aircraft impact, thereby ensuring that the reactor could, subsequently, be safely shut down.

5.10 External Hazards (Ref. 34)

External hazards represent a combination of man-made and natural hazards originating external to both the site and its facilities and processes. These are characterised as hazards that do not lend themselves to on-site control. The sensitivity of the design to such hazards must be well understood, and their effects controlled such that the safety of the reactor and its main associated buildings is assured.

In accordance with the GDA process, Hitachi-GE specified a 'generic site envelope' for external hazards (bounding assumptions where possible) for typical potential construction sites in Great Britain. By doing so, a successful GDA output would affirm the constructability at a range of known potential and suitable locations.

This site envelope defines values for maximum and minimum air temperatures; humidity; extreme winds/ tornados; rainfall, ice and snow; drought; electromagnetic interference from lighting and other external sources; maximum and minimum sea or river temperature; flooding potential; seismic events; loss of off-site power; aircraft impact; external fire, missiles and explosions etc.

ONR's GDA assessment has provided it with confidence that Hitachi-GE has identified external hazards thoroughly, has adopted an adequately conservative Generic Site Envelope (GSE), has considered appropriate combinations of hazards, has demonstrated the existence of adequate margins of safety from these assumptions, and has considered and incorporated relevant learning from the Fukushima event of 2011. Hitachi-GE has also demonstrated that it has considered and taken into account potential environmental changes, such as climate change, which may affect sites in Great Britain.

As a consequence, ONR is satisfied that Hitachi-GE has demonstrated, at a generic design level, the ability of the UK ABWR design to withstand, and maintain safety, during the appropriate range and magnitude of credible external hazards.

5.11 Internal Hazards (Ref. 40)

Internal hazards are those that originate within the site boundary, and are characterised by their ability to be eliminated, mitigated or controlled. Consequently, ONR has assessed Hitachi-GE's demonstration that the UK ABWR design has been subject to rigorous internal hazards identification analysis, characterisation, and control.

ONR has assessed the adequacy of Hitachi-GE's identification of internal hazards which could challenge the safe operation of the UK ABWR (such as internal fire and explosion, internal flooding, pressurised steam release, pipe whip, jet impact, conventional internal missiles (including turbine disintegration), dropped loads, electro-magnetic interference etc.). ONR has also assessed the claims made, in submissions by Hitachi-GE, on the robustness of the generic design to such hazards.

Protection against internal hazards is usually achieved by barrier segregation. However, in some cases, Hitachi-GE has stated that this is not practical. In such cases, ONR examined the safety arguments relating to these exceptions, and adopted a holistic view of the analysis methodology adopted. The most significant cases where segregation by barriers could not be achieved related to the Primary Containment Vessel (also referred to as the RCCV), the Main Steam Tunnel Room (MSTR) and the Main Control Room (MCR).

As a result of its assessment, ONR is satisfied that Hitachi-GE has demonstrated, at a generic design level, the ability of the UK ABWR design to withstand, and maintain safety, during the appropriate range and magnitude of credible internal hazards.

5.12 Structural Integrity (Ref. 50)

ONR has examined the structural integrity of the generic design (i.e. the ability to maintain structural integrity of static metal structures, systems and components which are important to nuclear safety such as pressure vessels, pressure boundaries, reactor internal components, storage tanks, internal support structures and the pressure boundary of pumps and valves) as detailed in Hitachi-GE's PCSR and supporting references.

As a result, ONR is able to conclude that the scope of Hitachi-GE's structural integrity considerations has been appropriate for GDA, with an adequate safety case having been presented for components requiring the highest levels of reliability. For lower classification components, during Step 4 of the GDA process, ONR has accepted examples of structural integrity demonstration, but notes that further work will be needed at the detailed design stage to fully substantiate safety case claims.

5.13 Mechanical Engineering (Ref. 42)

ONR specialist inspectors undertook detailed mechanical engineering assessment of significant safety related equipment (e.g. safety systems related to reactivity control, heat transfer and removal, containment of radioactive substances, cranes, pumps/valves, ventilation systems etc.).

ONR has confidence, as a result of its assessment, that the UK ABWR reflects both the satisfactory Japanese reference design and the lessons of operational experience.

However, the generic nature of the UK ABWR design at the GDA stage means that some relevant information cannot be made available until the detailed design and procurement stage. Consequently, ONR examined Hitachi-GE's design processes to satisfy itself that these will support the subsequent detailed mechanical engineering design to meet GB standards and regulatory expectations.

As a result of this mechanical engineering assessment, ONR is satisfied that the claims, arguments and evidence presented in the PCSR and supporting documentation provide an adequate generic safety case for the UK ABWR.

5.14 Control and Instrumentation (Ref. 30)

ONR has assessed the hardware and software aspects of the key control and instrumentation (C&I) systems (including C&I system architecture and diversity) used to operate the UK ABWR under normal conditions, and the safety systems used to maintain control of the plant in fault conditions.

This assessment has concluded that the PCSR and supporting documentation submitted by Hitachi-GE adequately identify and justify the key C&I safety-important systems expected in a modern nuclear reactor. The standards used by Hitachi-GE for C&I safety-important systems are broadly in accordance with those expected in the nuclear sector in GB.

The cyber security principles that we would expect to be considered as part of the justification of the C&I for a modern nuclear power plant are evident in the submissions.

As a result of this assessment, ONR is satisfied that the claims, arguments and evidence presented in the PCSR and supporting documentation for C&I provide an adequate generic safety case for the UK ABWR.

5.15 Electrical Engineering (Ref. 33)

ONR's electrical engineering assessment has considered the claims, arguments and evidence identified and substantiated by Hitachi-GE for electrical systems and equipment designed to support the delivery of nuclear safety functions.

Following a review of the PCSR and supporting references, the assessment has concluded that Hitachi-GE has adequately demonstrated, for GDA purposes, that the electrical power system for the UK ABWR can support key safety systems by providing robust electrical power in all operating modes, including under fault conditions.

ONR is also satisfied that Hitachi-GE modelling demonstrates that the UK ABWR's electrical power system has sufficient capability and stability to deliver the functional requirements identified for it.

In addition, the architecture of the UK ABWR electrical power system is judged to conform to international guidance, and Hitachi-GE has demonstrated sufficiently, for GDA, that the generic UK ABWR design could be connected to the GB grid system and achieve compliance with the requirements of the UK grid code.

5.16 Management of Spent Fuel (Ref. 49)

ONR has examined Hitachi-GE's proposals for the management of spent (irradiated) fuel.

Hitachi-GE's declared strategy for the management of UK ABWR spent fuel is that it will be stored under water (in the spent fuel pool, adjacent to the reactor in the R/B) for approximately ten years. It will be loaded and dried within a multi-purpose canister (MPC) which will then be weld sealed before export to an interim storage building. The MPCs will then be placed in to a concrete overpack and stored until the UK's planned Geological Disposal Facility (GDF) becomes available.

ONR considered the adequacy of Hitachi-GE's demonstration that associated risks are, or are capable of being, reduced SFAIRP.

ONR recognises that the detailed design of the spent fuel transport and storage infrastructure will be developed at a later stage. However, ONR did examine the technical feasibility of the design to accommodate safe interim storage of spent fuel, with current technology used to illustrate 'proof of concept'.

As a consequence of our assessment, ONR concludes that Hitachi-GE's proposals and outline design for the management of spent fuel align with UK Government policy, takes account of the disposability of the resultant spent fuel at a future GDF, and that the proof of concept has been demonstrated adequately for the purposes of GDA.

5.17 Nuclear Security (Ref. 47)

In addition to nuclear safety, ONR is responsible for the regulation of civil nuclear security.

Consequently, and complementary to the nuclear safety specialist assessments summarised elsewhere in this section of the report, ONR has examined Hitachi-GE's conceptual security arrangements for the UK ABWR.

In particular, ONR specialist nuclear security inspectors considered:

- The adequacy (and outputs) of Hitachi-GE's process for categorisation of nuclear and other radioactive material against theft or sabotage (to provide a proportionate and risk informed basis for its conceptual security plan);

- The adequacy (and outputs) of Hitachi-GE's process for identification and categorisation of critical assets (including Computer Based Systems Important to Safety) and vital areas (VA);

- The adequacy and proportionality of the physical protection of identified assets, and demonstration of defence in depth to meet 'National Objectives, Requirements and Model Standards for the Protective Security of Civil Licensed Nuclear Sites, Other Nuclear Premises and Nuclear Material in Transit' (NORMS); and

- Evidence that safety requirements had been considered when developing security arrangements.

ONR notes that, at a later stage, the future licensee will need to develop site specific arrangements that are compatible with ONR's Security Assessment Principles (Ref. 51), which has recently replaced NORMS.

ONR is satisfied that Hitachi-GE has satisfactorily conducted a comprehensive VA identification analysis (using a UK design basis threat), and has generated a well-defined list of areas requiring protection.

To prevent unauthorised access to such facilities, Hitachi-GE has adopted 'defence-in depth', through which, a series of sequential barriers and access controls ensure that only those personnel with appropriate authorisation can gain access to relevant areas.

As a consequence, ONR is satisfied that the claims, arguments and evidence presented in the Conceptual Security Arrangements are such that, from a nuclear security perspective, the design is suitable for construction in GB.

5.18 Radioactive Waste Management (Ref. 41)

In consultation with the environmental regulators, ONR has conducted an assessment of the generic aspects of radioactive waste management against legal requirements, assumed national waste management infrastructure and assumed permissions for disposal or discharge. The assessment was multi-disciplinary, involving contributions from a range of other specialist inspectors.

ONR's principal assessment objective was to satisfy itself that the proposed generic approach to radioactive waste management is consistent with the legal obligation to reduce safety risks SFAIRP.

ONR's assessment judged that Hitachi-GE has developed a systematic approach to the examination of options to manage radioactive wastes in order to secure good practice, and that it has applied this approach to all generic systems that will contribute to management of radioactive wastes. By doing so, Hitachi-GE has provided an adequate demonstration that it is technically feasible for UK ABWR radioactive wastes to be managed safely using established technology (in the context of the assumed generic site characteristics and predicted UK national waste infrastructure).

However, ONR did note that the generic radioactive waste management safety case gave significant focus to protection of the off-site environment, but provided less focus in some areas to the safety of on-site management of radioactive waste. Further work on this is anticipated during the site specific design stage.

As a consequence of its assessment, ONR concludes that:

- Hitachi-GE has developed a generic level radioactive waste management strategy that accords with GB law, UK government policy and ONR's regulatory expectations (including for Higher Activity Wastes (HAW));

- It is technically feasible for the liquid effluents that are expected to arise from normal operations of the UK ABWR to be effectively managed using proven technology; and

- All solid radioactive wastes expected to be generated during the operation of the UK ABWR can be appropriately managed and should be disposable at current or planned facilities within the UK.

Overall, ONR is satisfied that, at generic concept design level, it is feasible to minimise the generation of radioactive wastes, and to manage such wastes generated in accordance with GB legislative requirements and government policy.

5.19 Decommissioning (Ref. 32)

Although decommissioning of the UK ABWR is not scheduled to take place until at least 65 years after the completion of the GDA process, ONR has examined Hitachi-GE's submissions to ensure that ease of eventual decommissioning has been considered at the generic design stage.

The early generic nature of the design means that there are significant and unavoidable uncertainties regarding points of detail. Consequently, ONR has sought to assure itself that Hitachi-GE has adopted a precautionary approach to such uncertainty, so that the viability of the intended decommissioning strategy is not dependent on unrealistically optimistic assumptions relating to the operational performance of the UK ABWR.

ONR recognises that there is significant time to develop a detailed decommissioning plan, and to reflect global industry learning in its development. ONR notes that Hitachi-GE's assumed end-point for decommissioning is that the site be delicensed, with steps having been taken to ensure that the design is compatible with that objective.

As a consequence of its assessment, ONR has a high level of confidence in the feasibility of the eventual decommissioning of this reactor design.

As regards the obligation on operators of new nuclear plant to develop a Funded Decommissioning Programme (FDP), ONR has confirmed that Hitachi-GE's proposals are compatible with the government defined 'base case' (with any deviations having been appropriately justified).

5.20 Management of Safety and Quality Assurance (Ref. 43)

ONR has examined Hitachi-GE's arrangements, during GDA, for the management of safety and quality assurance (MSQA) (in particular, the arrangements for the production of the Hitachi-GE UK ABWR PCSR and supporting documentation).

Early in the process, Hitachi-GE established the expertise to produce a safety case manual, setting out its approach to the production of 'UK style' safety case documentation.

ONR's assessment confirmed that Hitachi-GE has maintained and continually improved its management processes for the development, approval and verification of the GDA UK ABWR PCSR and supporting documents. ONR's assessments and inspections provided sufficient evidence that the safety case has been produced to a consistent and acceptable standard.

The UK ABWR Generic PCSR Chapter 4 (Safety Management Throughout the Plant Lifecycle) provides suitable and sufficient information on safety and quality management to demonstrate that the UK ABWR would be constructed in accordance with the design and safety case requirements, and provides a good basis for moving forward into the site specific and licencing stages.

As indicated in ONR's GDA guidance, Hitachi-GE has specified the process that will be used to transfer, coherently, the safety case to a future licensee. This includes safety case assumptions that need to be tracked through construction, commissioning and operation.

Consequently, ONR is satisfied that Hitachi-GE's arrangements for MSQA, in relation to the PCSR, its supporting documentation, the control of the generic reactor design during GDA, and for the transfer of the PCSR and supporting documentation to a future licensee, are adequate.

5.21 Overall Adequacy of the Generic Safety Case

ONR's assessments in each technical area have considered the adequacy of the claims, arguments and evidence laid down with the generic PCSR and supporting documentation for that specific area. However, the completeness, coherence and consistency with which these topic-specific submissions have been brought together in a single generic safety case for the UK ABWR, has also been subject of ONR focus during GDA.

During the earlier Steps of GDA, ONR examined and ultimately satisfied itself of the adequacy of Hitachi-GE's approach to:

- development of a documented UK ABWR safety case strategy;
- securing of suitably qualified and experienced safety case professionals to deliver the strategy; and
- development of an understanding of GB regulatory expectations for modern standards safety cases.

During GDA Step 4, Hitachi-GE applied its safety case strategy to further develop the UK ABWR PCSR and the key supporting references. A number of draft revisions of the Generic PCSR were supplied to ONR in a controlled process to demonstrate that appropriate consolidations, additions and improvements were being made to satisfy ONR's expectations at this generic design stage.

Through this process, and ONR's wider technical assessments, it is concluded that the Generic safety case, as established by Revision C of PCSR (Ref. 19) and its supporting references (included within the Master Document Submission List, Ref. 22) is adequate to support the granting of a DAC.

6 Matters Arising during GDA for Consideration at the Site Specific Stage

The GDA process examines the generic PCSR of a generic reactor design (and associated buildings and activities included within the declared scope), and related underpinning documentation. As a consequence, there are a range of matters that cannot be decided or demonstrated at the generic stage.

Such ‘residual matters’ are comprised of:

- assumptions defined by Hitachi-GE (and referenced within the MDSL, Ref. 22) during the GDA process, which form a part of the basis on which the decision to issue a DAC is made, and which are recorded by Hitachi-GE for onwards provision to a future licensee;

- assessment findings identified by ONR during the GDA process, which will need to be addressed by the future licensee at a later stage (because they can only be effectively resolved during the detailed development or construction of the reactor). These will be subject to proportionate regulatory oversight; and

- minor shortfalls identified by ONR concerning the safety or security case, which are not considered significant enough to merit formal regulatory follow-up, but which ONR expects a future licensee to consider in a demonstrable manner.

As assumptions form a part of the evidence base for the issue of a DAC by ONR, it is a condition of the DAC that these be carried forwards by a future licensee (unless modified by a subsequent and appropriate change to the safety case or design of the UK ABWR). [NB. ONR also expects that the claims, arguments and evidence in the generic PCSR are carried forwards]. If these are not carried forwards appropriately, ONR reserves the right to re-examine relevant aspects of the safety case.

Consistent with this, Hitachi-GE has put arrangements in place to transmit these to a future licensee (see section 5.20). ONR’s expectation is that the assumptions will hold but, if not, reserves the right to re-examine relevant elements of the UK ABWR safety case.

Assessment findings are primarily concerned with the identification of significant aspects of the detailed design or site-specific safety/security case that are best, or can only, be addressed as the project progresses through the detailed design, construction and commissioning stages. An assessment finding will usually be specified where one or more of the following apply:

- site-specific information is required to resolve the matter (e.g. where site specific geological, seismic, flood risk etc. considerations are needed);

- detailed future licensee design choices need to be made at a later stage;

- the matter relates to operator-specific features, aspects or choices;

- the resolution requires future licensee choices on organisational matters;

- the matter can only be resolved during construction or commissioning of the plant;

- resolution of the matter requires a level of design detail that is beyond what can reasonably be expected in GDA (e.g. manufacturer/supplier input is required; or areas where the technology changes quickly, to avoid obsolescence of design).

The addressing of assessment findings will be subject to proportionate regulatory oversight delivered through ONR's normal regulation of new nuclear power station projects. However, the schedule for resolution of any findings needs to be determined by the future licensee in accordance with its intended development/ construction programme.

The clear identification of such assessment findings in GDA allows future licensees early visibility of design matters that they will need to address at an appropriate later stage. This enhances the certainty of GB regulatory expectations as the design enters the detailed design and construction phase, being one of the key benefits of the GDA process.

During the GDA process for the UK ABWR, ONR identified 201 assessment findings. A schematic breakdown of these by technical specialist area is included in Figure 5.

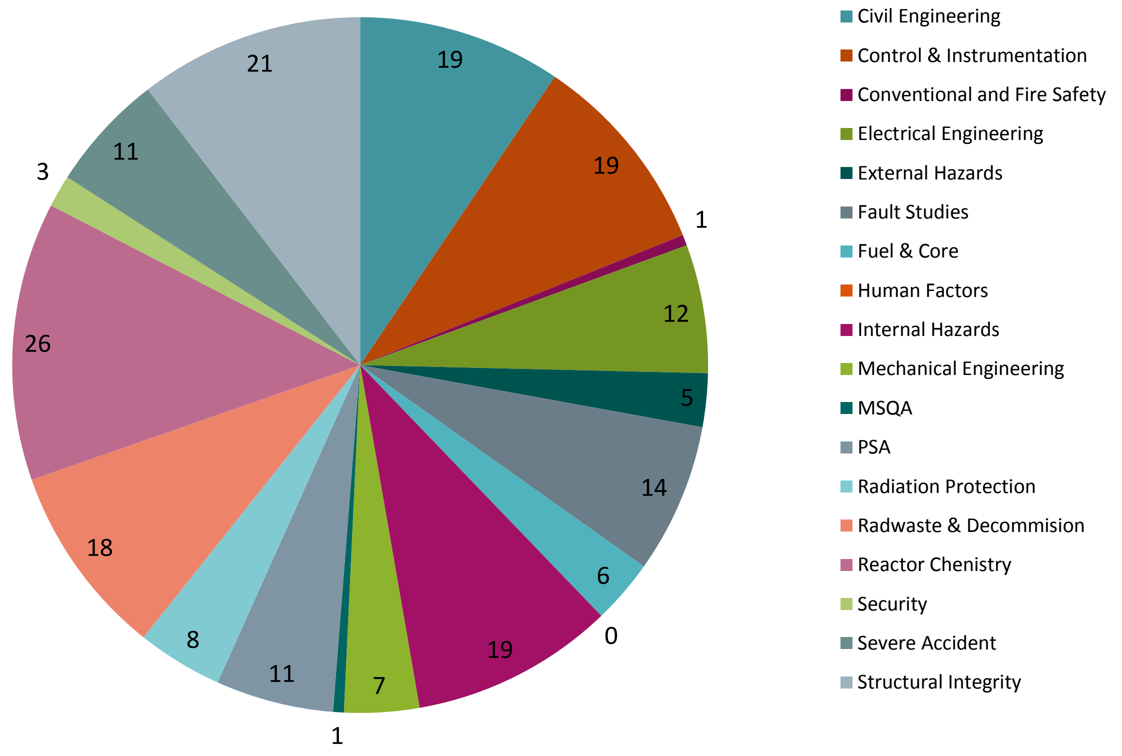


Figure 5 - Breakdown of UK ABWR Assessment Findings by Specialism

ONR has also identified a number of minor shortfalls. These are, as the name suggests, minor in nature and do not:

- undermine ONR’s confidence in the safety or security of the generic design;
- impair ONR’s ability to understand the risks associated with the generic design;
- require design modifications; or
- require further substantiation to be undertaken.

Whilst, in accordance with the regulatory principles of proportionality and targeting, ONR will not apply significant direct oversight to these, they are shortfalls none the less. Consequently, ONR expects any future licensee to consider these, and effect proportionate arrangements for their transparent management.

Future licensees will also need to make arrangements to accept the transfer and knowledge of the reactor and its underpinning safety case, which is important to ensure continuity of understanding of the safety case in the interests of continuity of effective safety management. In essence, transfer of such knowledge depends on the activities and capabilities of both the GDA Requesting Party and the future licensee.

At the time of production of this report, Horizon Nuclear Power Wylfa Limited had already applied (Ref. 24) for a Nuclear Site Licence (NSL) to install and operate two UK ABWR reactors at its Wylfa Newydd site on the Isle of Anglesey.

Whilst ONR is satisfied with Hitachi-GE’s arrangements to design, safety case and related knowledge to Horizon (section 5.20), Horizon’s arrangements to receive this information fall outwith the scope of the GDA process.

However, for completeness, ONR notes the collaborative working between Hitachi-GE and Horizon since step 2 of GDA, which provides confidence that knowledge transfer from Hitachi-GE to Horizon was well advanced at the time the Horizon NSL application was made.

Overall, ONR is satisfied that, during the UK ABWR GDA process, matters for consideration by future licensees have been adequately captured during the GDA.

7 Acceptability of the Design for Construction in Great Britain

ONR's recently published guidance on Risk Informed Decision Making (Ref. 15) identifies four main areas that we expect to be addressed adequately during GDA, as follows:

- That there are no further reasonably practicable improvements that could be made to the design at the generic design stage and, therefore, ONR is satisfied that the level of risk associated with the generic design has been reduced to an ALARP level;
- Relevant good practice has been incorporated into the design so far as is reasonably practicable, including comparisons with national and international standards;
- The RP has presented an adequate rationale for the evolution of the proposed design from its forerunners, examining why certain features were selected and others rejected to result in a safer design; and
- Risk assessment has been used to identify potential engineering and/or operational improvements in addition to confirming the numerical levels of safety achieved.

Whilst recognising the generic nature of the design, the ongoing need to address assessment findings identified during the GDA process, and the need to undertake more detailed site specific design work going forwards, ONR is satisfied that:

- The areas above have been adequately addressed for the purposes of GDA; and
- Hitachi-GE's submissions, made during the GDA process, are sufficient to demonstrate that the UK ABWR is capable of being built to the standards of safety and security required under GB law.

Consequently, ONR is satisfied that the Hitachi-GE UK ABWR design is acceptable for construction in GB, and that a DAC can be issued.

8 Conclusions

ONR is satisfied that:

- The generic PCSR for the UK ABWR and its supporting documentation are adequate for the purposes of the issuing of a DAC;

- In each case, in conducting their assessments, ONRs specialist inspectors have documented their satisfaction with, and acceptance of, the claims, arguments and evidence laid down within the generic safety case for their specialist area.

- The Conceptual Security Arrangements are adequate for the purposes of the issuing of a DAC;

- All ROs and RIs raised during GDA have been closed and the generic safety case updated to reflect Hitachi-GE's responses to these; and

- Hitachi–GE has adequate arrangements in place to transfer, to a future licensee, the UK ABWR generic safety case, assumptions made, assessment findings, and minor shortfalls noted.

As a consequence, and in conclusion, ONR is satisfied that:

- Hitachi-GE has demonstrated that this reactor design is suitable for construction and operation on nuclear licensed sites in GB, subject to:

    - Incorporation into the safety case/ security plan of site specific factors that may affect safety and/or security; and

    - The addressing of assessment findings and consideration of minor shortfalls identified during GDA, at appropriate times during the subsequent development of the reactor design or its construction and commissioning.

- a site-specific PCSR and security plan, and future associated safety reports, based on the generic PCSR, should be acceptable as the basis for the construction, commissioning and operation of a UK ABWR to meets GB safety and security legislative requirements;

- the GDA process for the UK ABWR has been successfully completed; and

- the generic design and underpinning safety/ security case for the UK ABWR are such that it is appropriate that ONR issue a DAC to Hitachi-GE for the UK ABWR.

9 Recommendations

It is recommended that:

- ONR issues a DAC to Hitachi-GE for the UK ABWR design;
- Annex 1 of the DAC defines the Design Reference by reference to the following documents:
    - Generic PCSR Rev C, dated 31 August 2017 submitted to ONR through letter HGNE-REG-157N;
    - Design Reference for UK ABWR, GA91-1104-0002-00001 (XE-GD-0178) Revision Number 8, dated 29 September 2017; and
    - Master Document Submission List (MDSL), GA91-0011-0003-00001 (XE-GD-0158) Revision Number 15, dated 28 November 2017.

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Glossary and Abbreviations

ABWR	Advanced Boiling Water Reactor

AFs	Assessment Findings
ALARP	As Low as Reasonably Practicable
ARs	Assessment Reports
BSC	Basis of Safety Case
BSL	Basic Safety Level
BSO	Basic Safety Objective (in ONR SAPs)
BWR	Boiling Water Reactor
CAE	Claims-Arguments-Evidence
C/B	Control Building
CDM	Construction Design and Management
C&I	Control and Instrumentation
DAC	Design Acceptance Confirmation (Office for Nuclear Regulation)
DSEAR	Dangerous Substances and explosive Atmosphere regulations
EA	Environment Agency
ECCS	Emergency Core Cooling System
EDG	Emergency Diesel Generator
FCVS	Filtered containment venting system
FDP	Funded Decommissioning Programme
GDA	Generic Design Assessment
GEP	Generic Environmental Permit (Environment Agency)
GSE	Generic Site Envelope
HAW	Higher Activity Wastes
Hx/B	Heat Exchange Building
IAEA	International Atomic Energy Agency
JPO	Joint Programme Office
JSCO	Joint Safety Case Office
LOCA	Loss of Coolant Accident
MCR	Main Control Room
MDEP	Multinational Design Evaluation Programme
MDSL	Master Document Submission List
MISV	Main Isolation Steam Valve
MPC	Multi-purpose Canister
MS	Minor Shortfalls
MSQA	Management of Safety and Quality Assurance
MSTR	Main Steam Tunnel Room

NORMS	National Objectives Requirements and Models Standards for the Protective Security of Civil Nuclear Licensed Sites
US NRC	United States Nuclear Regulatory Commission
NRW	Natural Resource Wales
NSL	Nuclear Site Licence
OECD	Organisation for Economic Co-operation and Development
ONR	Office for Nuclear Regulation
PCSR	Pre-construction Safety Report
PSA	Probabilistic Safety Analysis
PCV	Primary Containment Vessel
PWR	Pressurised Water Reactor
R/B	Reactor Building
RCCV	Reinforced Concrete Containment Vessel
RCW	Reactor Cooling Water
RHR	Residual Heat Removal
RI	Regulatory Issue
RO	Regulatory Observation
RP	Requesting Party
RPV	Reactor Pressure Vessel
RQ	Regulatory Query
SAP	Safety Assessment Principles (Office for Nuclear Regulation)
SFAIRP	So far as is reasonably practicable
SRV	Safety Relief Valve
SSC	Structures, Systems and Components
SSLC	Safety System Logic and Control
SoDA	Statement of Design Acceptability (Natural Resources Wales)
TAG	Technical Assessment Guide (Office for Nuclear Regulation)
TIG	Technical Inspection Guide (Office for Nuclear Regulation)
TSC	Technical Support Contractor
VA	Vital areas
WENRA	Western European Nuclear Regulators' Association

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