Office for Nuclear Regulation

New Reactors Division

Step 4 Assessment of External Hazards for the UK Advanced Boiling Water Reactor

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EXECUTIVE SUMMARY

Hitachi-GE Nuclear Energy Ltd is the designer and GDA Requesting Party for the United Kingdom Advanced Boiling Water Reactor (UK ABWR). Hitachi-GE commenced Generic Design Assessment (GDA) in 2013 and completed Step 4 of the GDA process in 2017.

This assessment report is my Step 4 assessment of the Hitachi-GE UK ABWR reactor design in the area of external hazards.

The scope of the Step 4 assessment is to review the safety, security and environmental aspects of the UK ABWR in greater detail, by examining the evidence, supporting the claims and arguments made in the safety documentation, building on the assessments already carried out for Step 3. In addition I have provided a judgement on the adequacy of the external hazards information contained within the Pre-Construction Safety Report (PCSR) and supporting documentation.

My assessment conclusion is:

- I am satisfied with the claims, arguments and evidence laid down within the PCSR and supporting documentation for external hazards.
- I consider that from an external hazards view point, the Hitachi-GE UK ABWR design is suitable for construction in the UK subject to future permissions and permits beings secured.

My judgement is based upon the following factors:

- The identification of external hazards has been thorough and complete;
- The screening of external hazards into GDA or into the site-specific phase has been performed in a logical and consistent manner
- Adequately conservative Generic Site Envelope (GSE) values for the hazards that have been screened in to GDA have been defined
- Combinations of hazards have been considered
- Adequate margins exist beyond the design basis to the point(s) where safety functions would no longer be achieved
- Hitachi-GE has analysed the potential effects of external hazards on the UK ABWR
- The demonstration of safety margins against external hazards and the link to protection of SSCs are clearly documented
- Due consideration has been given to lessons learnt post-Fukushima applicable to the external hazards area, including the implications of the IAEA director general’s report

The following matters remain, which are for a future licensee to consider and take forward in its site-specific safety submissions. These matters do not undermine the generic safety submission but will need licensee input/decision at a specific site.

- As a result of the assumptions made in the GSE for GDA, a future licensee shall perform a site-specific assessment to determine the design basis tornado wind speed. Depending on the results of the assessment, the implications of the maximum wind speed of a T2 tornado should be compared with the design withstand to demonstrate that the impact is acceptable with adequate margins.
- Due to the requirement for detailed design information and due to developments in methods of assessment, a future licensee shall consider sources of naturally-occurring Electromagnetic Interference (EMI) from extreme space weather events including geomagnetic storms, solar radiation storms, and radio blackouts. This shall include an assessment of hazard magnitudes, frequencies, and potential effects, along with reasonably practicable resilience enhancements to protect against these hazards to reduce risks ALARP.
- As a result of the assumptions made in GDA, a future licensee shall review the combinations of hazards at the site-specific stage to ensure that all reasonably

foreseeable combinations of hazards for a specific site have been included in the analysis.

- As a result of the assumptions made in GDA , a future licensee shall consider and implement adequate water sealing and/or elevation of the Heat Exchanger Building and transformer, Reactor Building, Control Building, Electrical Diesel Generator Buildings, and Backup Building. The determination of requirements shall be based on site-specific evaluation of external flooding beyond the design basis (BDB).
- As a result of assumptions made concerning BDB hazards in GDA, a future licensee shall consider whether or not the site-specific seismic analysis demonstrates that the generic site envelope's seismic hazard definitions are bounding. If the generic site envelope's seismic hazard definitions are not bounding, a future licensee shall assess the vulnerabilities of the UK ABWR to beyond design basis hazards assumed in the generic design to be bounded by generic site envelope seismic hazard definitions.

Overall, based on the samples I examined, I am satisfied that the claims, arguments and evidence laid down within the PCSR and supporting documentation submitted as part of the GDA process present an adequate safety case for the generic UK ABWR design in the area of external hazards. For this reason the UK ABWR should be awarded a DAC.

LIST OF ABBREVIATIONS

ACI	American Concrete Institute
ALARP	As Low As Reasonably Practicable
B/B	Backup Building
BSL	Basic Safety Level
BSO	Basic Safety Objective
CDF	Core Damage Frequency
CIGRE	International Council on Large Electrical Systems
DAC	Design Acceptance Confirmation
DBE	Design Basis Earthquake
EA	Environment Agency
EDG	Emergency Diesel Generator
EMI	Electromagnetic Interference
EVA	Extreme Value Analysis
FEH	Flood Estimation Handbook
FSR	Flood Studies Report
GDA	Generic Design Assessment
GSE	Generic Site Envelope
HVAC	Heating, Ventilation and Air Conditioning
IAEA	The International Atomic Energy Agency
LOOP	Loss of Offsite Power
LUHS	Loss of Ultimate Heat Sink
MDEP	Multi-national Design Evaluation Programme
NRW	Natural Resources Wales
OBE	Operating Basis Earthquake
OECD/NEA	Organisation for Economic Co-operation and Development Nuclear Energy Agency
ONR	Office for Nuclear Regulation
PCSR	Pre-construction Safety Report
PSA	Probabilistic Safety Assessment
PSR	Preliminary Safety Report
RGP	Relevant Good Practice
RI	Regulatory Issue
RO	Regulatory Observation
RQ	Regulatory Query
RP	Requesting Party
SAPs	Safety Assessment Principles

SDV	Screening Distance Value
SFAIRP	So Far As Is Reasonably Practicable
SLA	Site Licensing Application
SMA	Seismic Margins Assessment
SoDA	Statement of Design Acceptability
SSC	System, Structure (and) Component
SSER	Safety, Security and Environmental Report
SSG	Specific Safety Guide
TAG	Technical Assessment Guide
TSC	Technical Support Contractor
US NRC	United States (of America) Nuclear Regulatory Commission
UK ABWR	United Kingdom Advanced Boiling Water Reactor
UKCP09	United Kingdom Climate Projections 2009
WENRA	Western European Nuclear Regulators' Association

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Annexes

1 INTRODUCTION

1. This assessment report details my Step 4 Generic Design Assessment (GDA) of Hitachi-GE's UK ABWR reactor design in the area of external hazards.

1.1 GDA Background

2. Information on the GDA process is provided in a series of documents published on our website (**http://www.onr.org.uk/new-reactors/index.htm)**. The outcome from the GDA process sought by Requesting Parties such as Hitachi-GE is a Design Acceptance Confirmation (DAC) for ONR and a Statement of Design Acceptability (SoDA) for the Environment Agency (EA) and Natural Resources Wales (NRW).

3. The GDA of the UK ABWR has followed a step-wise approach in a claims-arguments-evidence hierarchy which commenced in 2013. 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. The reports in individual technical areas and accompanying summary reports are also published on ONR's website.

4. The objective of the Step 4 assessments is to undertake an in-depth assessment of the safety, security and environmental evidence. Through the review of information provided to ONR, the Step 4 process should confirm that Hitachi-GE:

- Has properly justified the higher-level claims and arguments.
- Has progressed the resolution of issues identified during Step 3.
- Has provided sufficient detailed analysis to allow ONR to come to a judgment of whether a DAC can be issued.

5. The full range of items that might form part of the assessment is provided in ONR's 'GDA Guidance to Requesting Parties' (http://www.onr.org.uk/new-reactors/ngn03.pdf). These include:

- Consideration of issues identified in Step 3.
- Judging the design against the Safety Assessment Principles (SAPs) and whether the proposed design reduces risks to ALARP.
- Reviewing details of the Hitachi-GE design controls, procurement and quality control arrangements to secure compliance with the design intent.
- Establishing whether the system performance, safety classification, and reliability requirements are substantiated by the detailed engineering design.
- Assessing arrangements for ensuring and assuring that safety claims and assumptions are realised in the final as-built design.
- Resolution of identified nuclear safety and security issues, or identifying paths for resolution.

6. All of the regulatory issues (RIs) and regulatory observations (ROs) issued to Hitachi-GE during Steps 2 to 4 are also published on ONR's website, together with the corresponding Hitachi-GE resolution plan.

1.2 Scope

7. The scope of my assessment is detailed in my assessment plan (Ref. 1).

8. In the earlier Steps 2 and 3 of GDA, the underpinning safety claims and arguments were assessed (Refs. 2,3). The Step 4 assessment has built upon those earlier assessments, looking in greater detail at safety case evidence presented by the Requesting Party (RP) that underpins the safety claims and arguments examined

during Steps 2 (Ref.2) and 3 (Ref.3) of GDA. Evidence to underpin safety claims and arguments was incomplete in the area of external hazards at the end of Step 3.

9. For external hazards, "evidence" is interpreted as being a demonstration of conformance with the ONR Safety Assessment Principles (SAPs) and with other established relevant good practice for the identification and treatment of external hazards. This includes evidence that:

- The identification of external hazards has been thorough and complete
- The screening of external hazards into GDA or into the site-specific phase has been performed in a logical and consistent manner
- Adequately conservative Generic Site Envelope (GSE) values for the hazards that have been screened in to GDA have been defined
- Reasonably foreseeable combinations of hazards have been considered
- Adequate margins exist beyond the design basis to the point(s) where safety functions would no longer be achieved
- The potential effects of external hazards on the UK ABWR have been analysed
- The demonstration of safety margins against external hazards and the link to protection of SSCs are clearly documented
- Due consideration has been given to lessons learnt post-Fukushima applicable to the external hazards area, including the implications of the IAEA director general's report

10. In addition to examining the evidence demonstrating the points listed above, I also focussed the scope of my assessment on the specific elements set out in the Step 3 Assessment Report (Ref.3) as requiring further consideration during Step 4. These elements are as follows**:**

- Detailed examination of external hazards Topic Reports
- Detailed examination of the Generic Site Envelope Topic Report and supporting documents.
- The selection and processing of source data and the application of climate change in external hazards submissions.
- Cross-cutting issues identified in other discipline areas

11. The scope of my assessment is aligned with ONR and international guidance listed in section 2.1 of this report as relevant to new nuclear plant generic designs. It is also aligned with the ONR Guidance to Requesting Parties.

1.3 Method

12. My assessment complies with internal guidance on the mechanics of assessment within ONR:

- Guidance on demonstration of ALARP (Ref. 4).
- Guidance on production of reports (Ref.5).
- Peer review of legal and technical assurance (Ref.6).

2 ASSESSMENT STRATEGY

2.1 Standards and criteria

13. The standards and criteria adopted within this assessment are principally the Safety Assessment Principles (SAPs) (Ref. 7), internal TAGs (Ref. 8), relevant national and international standards and relevant good practice informed from existing practices adopted on UK nuclear licensed sites.

2.1.1 Safety Assessment Principles

14. The key SAPs applied within the assessment are included within annex 1and discussed within the report as appropriate.

2.1.2 Technical Assessment Guides

15. The TAGs that have been used as part of this assessment are set out in annex 2

2.1.3 National and international standards and guidance

16. The national and international standards and criteria that I have used to judge the adequacy of the arguments in the area of external hazards for the UK ABWR are:

17. Relevant IAEA standards (Ref. 9):

- IAEA Safety Standards Series - Site Evaluation for Nuclear Installations – NS-R-3
- IAEA Safety Standards Series – Volcanic Hazards in Site Evaluation for Nuclear Installations – Specific Safety Guide (SSG)- 21
- IAEA Safety Standards Series – Meteorological and Hydrological Hazards in Site Evaluation for Nuclear Installations – SSG-18
- IAEA Safety Standards Series – External Events Excluding Earthquakes in the Design of Nuclear Power Plants – NS-G-1.5
- IAEA Safety Standards Series - Seismic Design and Qualification of Nuclear Power Plants - NS-G-1.6
- IAEA Safety Standards Series - External Human Induced Events in Site Evaluation for Nuclear Power Plants – NS-G-3.1
- IAEA Safety Standards Series - Seismic Hazards in Site Evaluation for Nuclear Installations – SSG-9
- IAEA Safety Standards Series - Geotechnical Aspects of Site Evaluation and Foundations for Nuclear Power Plants – NS-G-3.6

18. WENRA references (Ref.10):

- RHWG Report on Safety of new NPP (Nuclear Power Plant) designs

2.2 Use of Technical Support Contractors (TSCs)

19. It is usual in GDA for ONR to use TSCs, for example to provide additional capacity, to enable access to independent advice and experience, analysis techniques and models, and to enable ONR's inspectors to focus on regulatory decision making.

20. I engaged Technical Support Contractors during Step 4 to support my assessment of external hazards for the UK ABWR in relation to the following specific aspects:

- Detailed examination of external hazards Topic Reports
- Detailed examination of the Generic Site Envelope Topic Report and supporting documents.

- The selection and processing of source data (including consistency check across the various submissions) and the application of climate change in external hazards submissions.
- The Generic Site Envelope hazard definitions and adequacy of margins.
- Detailed examination of evidence for the consideration of cliff edge effects
- Detailed examination of combinations of hazards, including the treatment groups of external hazards within the analysis rather than specific individual hazards, and appropriateness of the reliance on expert judgment.
- Detailed examination of margins beyond the design basis to the point(s) where safety functions would no longer be achieved
- Seismic margins analysis and seismic fragility
- Consideration of lightning protection claims including justification against the appropriate British Standard.
- Detailed consideration of external flooding claims, including the application of the dry site concept, the treatment of rainfall, and the combinations of flooding hazards.
- Examination of the Accidental Aircraft Impact Strategy
- Consideration of lessons learnt post-Fukushima applicable to the external hazards area, including the implications of the IAEA director general's report
- Cross-cutting issues identified in other discipline areas.

21. I used the TSC report (Ref.11) to inform my Step 4 assessment of the UK ABWR for external hazards. It should be noted that whilst the TSC has undertaken detailed technical reviews, this was done under close direction and supervision from myself, and the regulatory judgement on the adequacy of the external hazards evidence for the UK ABWR has been made exclusively by ONR.

2.3 Integration with other assessment topics

22. GDA requires the submission of an adequate, coherent and holistic generic safety case. Regulatory assessment cannot therefore be carried out in isolation as there are often safety issues of a multi-topic or cross-cutting nature. The following cross-cutting issues have been considered within this assessment:

- External hazards are potential fault initiators, and this has been considered as part of the Fault Studies Step 4 assessment report. However the completeness of the list of hazards considered by Hitachi-GE and input into the design basis analysis has been considered as part of this assessment.

- The ONR PSA inspectors have considered the screening and prioritisation of external hazards as part of their review of the Hitachi-GE PSA. I have provided advice and guidance to the PSA team on external hazards matters but the assessment of the screening and prioritisation of external hazards for PSA is assessed within the PSA Step 4 assessment report.

- External hazards load definitions are considered as part of this assessment. Hitachi-GE then input these definitions into the Basis of Safety Case documents for individual SSCs. The ability of a Structure, System or Component to deliver its safety functions during normal operations (including for shutdown), fault sequences and accident conditions with adequate consideration of external hazards loads are considered in the systems chapters of the PCSR and assessed by the relevant engineering specialisms. For example, the primary means of protection against external hazards is the civil structures and these are considered with the Civil Engineering Step 4 assessment report.

- External hazards will need to be taken into account as part of the qualification of equipment to confirm that structures, systems and components will perform their allocated safety function(s) in all normal operational, fault and accident conditions identified in the safety case and for the duration of their operational lives. ONR discipline inspectors including Electrical, Control and Instrumentation, Radioactive Waste and Mechanical Engineering inspectors have considered this requirement and determined that the qualification of equipment will need to be addressed by a future licensee during the detailed design phase as part of normal business.

2.4 Sampling strategy

23. It is seldom possible, or necessary, to assess a safety case in its entirety, therefore sampling is used to limit the areas scrutinised, and to improve the overall efficiency of the assessment process. Sampling is done in a focused, targeted and structured manner with a view to revealing any topic-specific, or generic, weaknesses in the safety case.

24. I performed a detailed assessment of Hitachi-GE's screening process and analysis of the 14 external hazard groups retained within GDA, including combinations of hazards, and the way that external hazard definitions were input into design basis analysis, interfacing with the fault studies discipline.

25. I adopted a sampling approach towards examining the linkages between external hazards and other disciplines by examining the way external hazards definitions were applied as loading functions within the Engineering topic areas. My sampling approach was based on the importance of these loading functions, either due to their widespread use within the discipline (for example, civil structures) or due to the importance of the system in terms of its overall contribution to overall core damage frequency as revealed by PSA analysis (for example, the HVAC system).

2.5 Out of scope items

26. The following items have been agreed with Hitachi-GE as being outside the scope of GDA:

- Site-specific aspects such as the detailed assessment of external hazard design basis values for a particular site.
- Assessment of the seven external hazard groups that Hitachi-GE screened into site licensing (although the process to screen hazards into or out of GDA is in scope).
- Consideration of emergency arrangements requirements including those requirements arising from external hazards initiating events.

27. A future licensee will consider the above items during the site-specific phase as part of normal business.

3 REQUESTING PARTY'S SAFETY CASE

The generic Pre-construction Safety Report (PCSR) is the lead document in the submission by Hitachi-GE for Step 4 of the generic design assessment (GDA) process. The chapters of the PCSR that were assessed as part of the external hazards topic stream are listed in the table below. These chapters summarise Hitachi-GE's key external hazards claims for the UK ABWR. The topic reports and other supporting documents underpin the PCSR chapters and provide arguments and evidence that confirm the claims made in the PCSR.

The Hitachi-GE safety case for external hazards is documented in the PCSR chapters, topic reports, and supporting documents listed in the table below. The revisions assessed as part of GDA step 4 are listed, along with a brief description of the content, confirmation that the documents are within the scope of the external hazards assessment, and a summary of the arguments provided in each document type:

Submission Title	Content	Link to Assessment Scope	Summary Arguments
<u>PCSR</u> PCSR – Chapter 2 "Generic Site Envelope" (XE-GD-0213), Chapter 6 "External Hazards" (AE-GD-0168) Revisions assessed comprise Rev B, Rev C	Preconstruction Safety Report. Summary of principal arguments and overall basis of the safety case.	Within scope. This is the head document of the safety case hierarchy of documents.	A logical hierarchy of documents supports the UK ABWR nuclear safety case. Generic site envelope and external hazards parameters are identified.
<u>External Hazards & Generic Site Envelope – Topic Reports</u> AE-GD-0126 Topic Report on External Hazard Protection, Revisions assessed comprise Revs 2, 3 and 4 AE-GD-0201 Topic Report on External Hazards Combinations, Revisions assessed comprise Rev 0, 1 and 2 XE-GD-0183 Topic Report on Generic Site Envelope, Revisions assessed comprise Revs B – G	The Topic Report on External Hazards protection describes the identification process for individual external hazards and the derivation of the list of individual external hazards to be considered in the UK ABWR SSC design. The relationship between safety functions and identified external hazard groups, and the corresponding general protection policy are also described. The Topic Report on Combined External Hazards describes the identification process for	Within scope. Key document for external hazards assessment. Within scope. Key document for external hazards assessment.	Appropriate identification, selection and evaluation techniques have been applied with regard to external hazards and the Generic Site Envelope relevant to the UK context has been defined for GDA.

Submission Title	Content	Link to Assessment Scope	Summary Arguments
	combined external hazards and the derivation of the list of external hazards combinations to be considered in UK ABWR SSC design. . The Topic Report on The Generic Site Envelope describes the methodology for the definition of generic site conditions and values for appropriate external hazards to be used in GDA.	Within scope. Key document for the definition of the Generic Site Envelope assessment.	
External Hazards & Generic Site Envelope – Supporting Documents XE-GD-0316 Support Document on Meteorology and Hydrology for Generic Site Envelope Revisions assessed comprise Rev 1 JE-GD-0086 Support Document on Soil and Seismic Input for Generic Site Envelope Revisions assessed comprise Rev 1,2 and 3 3E-GD-A0155 Support Document on EMI for Generic Site Envelope Revisions assessed comprise Rev 1 – 4 AE-GD-0176 Accidental AIA Strategy Revisions assessed comprise Rev 1 and 2	The supporting documents to the Topic Reports summarise the evidence provided to underpin the arguments presented in the Topic Reports and the claims made in the PCSR.	Within scope. Key documents supporting the assessment.	Appropriate identification, selection and evaluation techniques have been applied with regard to external hazards and the Generic Site Envelope relevant to the UK context has been defined for GDA.

Submission Title	Content	Link to Assessment Scope	Summary Arguments
AE-GD-0685 Beyond Design Basis Margin Evaluation for External Flood on GDA Revisions assessed comprise Rev.0 LE-GD-0299 Cliff Edge Effect on Civil Engineering Revisions assessed comprise Revs 0, 1 and 2 HPE-GD-H061 BDB design margins for the Class 1 and 2 HVAC systems Revisions assessed comprise Rev 0 XE-GD-0487 UKABWR Evaluation of External Hazards - Enthalpy and Temperature Revisions assessed comprise Rev B			

4 ONR STEP 4 ASSESSMENT

28. This assessment has been carried out in accordance with ONR internal guidance on the “Purpose and Scope of Permissioning” (Ref.12).

4.1 Scope of Assessment Undertaken

29. This assessment has been undertaken in accordance with the detailed scope given in section 6 of this report.

4.2 Assessment

4.2.1 External Hazards Selection and Screening

30. Hitachi-GE has applied a systematic process to identify, group and screen external hazards in accordance with SAP EHA.1 on the identification and characterisation of hazards (Ref. 13). Hitachi-GE has referred to a wide range of international and regulatory guidance and standards, including ONR TAG 13 (Ref.8) and WENRA reference levels (Ref.10), as reference sources to inform the production of the comprehensive list. This resulted in a list of 167 external hazards which were then combined into 22 hazard groups. These groups were then screened to determine whether the hazard groups should be considered as part of GDA, deferred to the site-specific stage, or screened out entirely.

31. As a result of the screening process, Hitachi-GE determined that 14 of the hazard groups should be screened in to GDA, and 7 should be deferred for consideration at the Site Licensing Application (SLA) phase. Hitachi-GE’s basis for determining whether a hazard should be considered as part of GDA or deferred to SLA was the site-specific nature of the hazard group. The hazard groups that have been deferred to SLA need significant input from site specific data to classify their frequency in a meaningful way. I agree with this conclusion. ONR’s Guidance to Requesting Parties (Ref.14) states that “the definition of the site envelope can be as broad or as narrow as the requesting party wishes. However, it should be unambiguous and specify any site-related characteristics which have been explicitly included within or excluded from that definition.” Hitachi-GE’s screening process meets the intent of this guidance. It is Hitachi-GE’s decision as to which hazards to consider as part of the generic site envelope. However Hitachi-GE’s choice of hazards is logical and is clearly documented.

32. Of the 22 hazard groups, only one was screened out from consideration entirely. This is the “Extra-terrestrial object” external hazard group which was screened out from GDA and which was not required to be deferred to SLA assessment. Hitachi-GE calculated the frequency of occurrence as 1.9×10^{-8} per year of an extra-terrestrial object large enough to cause damage hitting any specific area on earth of the size of an ABWR site. SAP EHA.19 states that “non-discrete hazards may be excluded where… their frequency of exceedance on their hazard curve is below once in ten million years” and therefore Hitachi-GE’s decision to screen out this hazard is in line with the intention of this SAP. It is also aligned with IAEA guidance which states (Ref. 15) that external hazards presented by meteorites are usually excluded from consideration in the design of nuclear power plants as the frequency of occurrence of a significant meteorite impact on a particular area is less than 10-7 per year. In my view, Hitachi-GE has presented an adequate justification for screening out this hazard. from GDA and it is therefore accepted. The 7 hazards that have been deferred to SLA will need detailed analysis by a future licensee at the site-specific phase. A future licensee will also need to review the 14 hazards that have been screened into GDA to ensure that they bound the site-specific values which will need to be derived at the site-specific phase. This will need to be performed as part of normal business.

33. Hitachi-GE has calculated Generic Site Envelope (GSE) values for the 14 hazards that have been screened in to GDA. These values are discussed further below.

4.2.2 External Hazards Generic Site Envelope Values

4.2.2.1 AIR TEMPERATURE

34. The air temperature hazard group consists of high air temperature, low air temperature, and humidity (which Hitachi-GE expresses as enthalpy). Hitachi-GE has determined GSE values for these hazards based on applying Extreme Value Analysis (EVA) to historically recorded data from the eight candidate sites identified for nuclear new build. Hitachi-GE acknowledges that the data sets available are quite short, at an average of 33 years per station, but they have been analysed to calculate annual probabilities of exceedance of 10^{-2} /yr and 10^{-4} /yr for each of the candidate sites.

<u>High and Low Air Temperature</u>

35. Hitachi-GE's analysis shows that Wylfa bounds the other seven sites with regard to high air temperature. Therefore, for high air temperature, Hitachi-GE undertook a further EVA by applying a 55 year data set available from RAF Valley to underpin a more robust assessment of air temperature. Based on this further evaluation, Hitachi-GE defines the high air temperature GSE values, including the UKCP09 Medium emissions scenario predictions for the 10^{-4} /yr annual probability of exceedance at the 84% confidence level as follows:

- Maximum Hourly Air Temperature
  - 2080 45.9°C
  - 2120 47.8°C
- Maximum 6h Mean Air Temperature
  - 2080 45.9°C
  - 2120 47.8°C
- Maximum 12h Mean Air Temperature
  - 2080 41.2°C
  - 2120 43.1°C

36. Hitachi-GE estimates the GSE Low Air Temperature values without assuming Climate Change effects. As Climate Change generally predicts an increase in air temperatures, I consider this to be a conservative approach for the purposes of GDA. I consider this reasonable for the purposes of GDA. However, further work will be required at the site specific phase in order to substantiate this approach as part of normal business. Hitachi-GE defines the 10^{-4} /yr Low Air Temperature value as -22.5°C.

37. I consider the high air temperature and low air temperature values to be adequate for the purposes of GDA. They have been calculated using a reasonable methodology and data set in line with the expectations of SAPs EHA.4 – Frequency of Initiating Event and EHA.11 – Weather Conditions. The values are consistent with values calculated by other requesting parties for UK candidate sites and are conservative when compared to code-based values including values from the relevant Eurocode (Ref.16) Further analysis will be needed at the site-specific phase as part of normal business to ensure that these values take into account all historical and instrumental data relevant to the Wylfa site.

Humidity

38. Humidity is a measure of the moisture content of the air. Humidity and high air temperature are combined in calculating enthalpy values, which are used in the design of the heating and ventilation (HVAC) systems. Hitachi-GE has defined the enthalpy GSE values in accordance with the UKCP09 Medium emissions scenario predictions for the 10^{-2} and 10^{-4} /yr annual probabilities of exceedance at the 84% confidence level. The results are as follows::

- Maximum Hourly Enthalpy
  - 10^{-2} /yr 80.2 kJ/kg
  - 10^{-4} /yr 90.5 kJ/kg
- Maximum 6h Mean Enthalpy
  - 10^{-2} /yr 79.3 kJ/kg
  - 10^{-4} /yr 90.5 kJ/kg
- Maximum 12h Mean Enthalpy
  - 10^{-2} /yr 76.3 kJ/kg
  - 10^{-4} /yr 90.2 kJ/kg

39. These values represent an update to previous calculations performed by Hitachi-GE (Ref.17). The update consisted of:

- The removal of two outliers from the Met Office dew point temperature data which the Met Office confirmed were spurious values that had been misreported in the supplied dataset.
- The removal of excess conservatism introduced in the previous calculations due to:
  - Performing separate extreme value calculations of air temperature and of humidity without accounting for the relationship between the two individual hazards. This was corrected using a joint probability method to account for this relationship.
  - The application of climate change to the two separate hazards before combination. This was corrected by the application of climate change to the final calculated enthalpy values.

40. Hitachi-GE then completed a benchmarking exercise on its revised GSE enthalpy values, comparing the 10^{-2} GSE values with the wet bulb and dry bulb temperatures from BS4485 – Water Cooling Towers. The Hitachi-GE values were found to be conservative compared to these code-based values.

41. I consider Hitachi-GE's approach adequate for GDA. The methodology used to calculate enthalpy is in line with relevant good practice, and the removal of excess conservatism from previous calculations has been adequately explained and evidenced. The conclusions reached are reasonable in line with the expectations of SAPs EHA.4 – Frequency of Initiating Event and EHA.11 – Weather Conditions. Further analysis will be needed at the site-specific phase as part of normal business to ensure that these values take into account all historical and instrumental data relevant to the Wylfa site.

4.2.2.2 WIND

42. The wind hazard group consists of two hazards - extreme winds and tornados. These are considered separately below.

Extreme Wind

43. In order to derive a GSE value for extreme wind, Hitachi-GE began by calculating maximum wind speeds for the proposed UK candidate sites using US and European codes. The 10 minutes mean wind speed was calculated in accordance with BS EN 1991 EC1-1-4 (Ref.18) for annual exceedances of 10^{-2}/yr and 10^{-4}/yr. The 3 second gust wind speed was calculated using ASCE 7-10 (Ref.19), also for the 10^{-2}/yr and 10^{-4}/yr annual probabilities of exceedance. The result was that Wylfa wind speeds were found to be bounding for the 8 proposed candidate sites for both the 10 minute mean and 3 second gust. Hitachi-GE then decided to refine these values by comparing them with the results of a site-specific analysis that Horizon Nuclear Power has provided for the Wylfa site. I consider this to be a reasonable approach to ensure adequately conservative values are used in the GSE given the bounding nature of the code-based study.

44. The analysis provided by Horizon Nuclear Power is documented within a Nuclear Safety, Meteorological & Hydrological Hazard Assessment (NSMHHA) report. The NSMHHA report is a site-specific submission and ONR has not yet assessed this report in detail. However, the EVA methodology used in this report is a widely used, standard methodology and the results for extreme wind are consistent with and conservative when compared to the code-based approach. Therefore, in my view it is appropriate to make use of these values when considering the GDA GSE.

45. Hitachi-GE has defined the extreme wind GSE values at the 84th percentile as:

- 3-Second Gust
  - 10^{-2} /yr 43.4 m/s
  - 10^{-4} /yr 50.7 m/s
- 10 Minute Mean
  - 10^{-2} /yr 33.1 m/s
  - 10^{-4} /yr 38.6 m/s

46. The extreme wind projections do not include an allowance for climate change. This is based on the fact that in UKCP09, changes in 30-year mean wind speeds relative to the 1961-1990 baseline suggest that the central estimates of change are very small (less than 0.2 m/s) and suggest a reduction in wind speeds by the 2080s. In my view, although the level of uncertainty is high, considering the conservatisms included in the assessment of extreme wind for GDA and the UKCP09 projections, this approach is adequate for GDA. During the site-specific phase, a future licensee will need to consider the potential effects of climate change on extreme wind in detail as part of normal business.

Tornado

47. In the Topic Report on the Generic Site Envelope (Ref.20) Hitachi-GE states that the probability of exceedance for a T2 tornado for most candidate UK sites can be shown to have a probability of annual exceedance less than 10^{-4}, however no source is provided for this claim. I have also identified that an earlier version of the report (Ref.21), discusses the tornado hazard in more detail and states that the annual probability of exceedance of a T2 Tornado in “Southern Britain”, the most tornado-prone region of the UK, as 1.03×10^{-4} /yr. The probability of annual exceedance of such a tornado in “Outer Britain”, the least tornado-prone region of the UK (where

Wylfa is situated) is as low as 0.5 x 10^{-5} /yr. I note that the values are consistent with those reported in the TORRO report (Ref.22). However, I am uncertain as to why the prose has changed between revisions of the Topic Report.

48. Both versions of the topic report state that the minimum wind speed of a T2 Tornado is 33 m/s, and Hitachi-GE claims that this is bounded by all the 10^{-4} wind speeds reported above. In undertaking my assessment, however, I note that the maximum wind speed of a T2 tornado is 41 m/s according to the TORRO scale. This value exceeds the 10 minute mean wind speed at the 10^{-4} frequency of 38.6 m/s, although it continues to be bounded by the 3 second gust of 50.7 m/s.

49. I have consulted the TORRO report which states that the peak wind speeds of a tornado are typically sustained for only short durations, and usually less than one minute. For a T2 tornado a value of 10 seconds is provided. Consequently, although the maximum tornado wind speed is bounded by the three second gust at 10^{-4} the duration of peak T2 wind speeds is likely to be slightly greater.

50. The data from the TORRO report is more than 30 years old. Therefore I would have expected this report to be supplemented with more recent data to inform the tornado hazard. The PSA prioritisation report (Ref.23) uses more recent data to generate tornado hazard curves, although I note that the (Ref.24) itself raises concerns over the tornado frequencies applied in the PSA, in terms of the probability of occurrence of a tornado in the British Isles (1.2 per 10,000 km^2) compared with England (2.2 per 10,000 km^2).

51. Given the shortfalls with the tornado hazard highlighted above, but also recognising the need for the frequency and magnitude of the tornado hazard to be determined at the site specific stage, I raise the following Assessment Finding:

52. As a result of the assumptions made in the GSE for GDA, a future licensee shall perform a site-specific assessment to determine the design basis tornado wind speed. Depending on the results of the assessment, the implications of the maximum wind speed of a T2 tornado should be compared with the design withstand to demonstrate that the impact is acceptable with adequate margins.

53. As part of my assessment of the hazard I have also considered missiles (wind-born debris) associated with the tornado hazard. I note that missiles are covered in the PSA prioritisation report and the Topic Report on the Generic Site Envelope (Ref 21), but not within the PCSR Chapter 2 on the Generic Site Envelope.

54. Hitachi-GE has adopted US NRC practice for deriving the design basis tornado missile impact, given the lack of UK data. Hitachi-GE has selected region III from US NRC Guide 1.76 (Ref.25) as being representative of the UK, as this corresponds to areas of lowest tornado frequency in the US. The design basis tornado for this region corresponds to a T5, with a maximum wind speed of 72 m/s and a probability of exceedance of 10-7 /yr. Consequently, in my view the design basis missile characteristics are adequate for the UK ABWR design basis tornado, although more conservative than expected given the UK context.

4.2.2.3 RAINFALL AND ICE

55. The rainfall and ice hazard group consists of extreme rainfall and ice, which is further divided into frazil ice, rime ice, and barrier ice. These are considered separately below.

Rainfall

56. Hitachi-GE has defined the maximum precipitation for the Generic Site by taking into account historical data for the 8 candidate sites in accordance with guidance in the Ecology and Hydrology's Flood Estimation Handbook (FEH) (Ref.26) and Flood Studies Report (FSR) (Ref.27). Hitachi-GE has then added an allowance for climate change in accordance with guidance in the Environment Agency's publication, Adapting to Climate Change: Advice for Flood and Coastal Erosion for Risk Management Authorities (Ref.28).

57. Using the methodology described above, Hitachi-GE calculated extreme rainfall depths for 15 minute, 30 minute, 1 hour and 1 day durations for annual exceedance of 10^{-2} and 10^{-4} for all 8 candidate sites. Hitachi-GE then defined the GSE Design Basis for several rainfall durations for the 10^{-4} /yr exceedance frequency at the 84th percentile by taking the maximum values from the eight candidate sites. The resulting rainfall GSE values are as follows:

- 15min
  - Present Day 61.8 mm
  - 2120's 86.5 mm
- 30min
  - Present Day 91.2 mm
  - 2120's 127.7 mm
- 1 h
  - Present Day 116.0 mm
  - 2120's 162.4 mm
- 24 h
  - Present Day 220.5 mm
  - 2120's 308.7 mm

58. I consider Hitachi-GE's application of relevant guidance to derive extreme rainfall values for the GSE to be adequate for GDA in line with the expectations of SAPs EHA.4 – Frequency of Initiating Event and EHA.11 – Weather Conditions. The FEH and FSR guidance is standard guidance in widespread use in the UK for the estimation of rainfall in the planning and assessment of flood defences. It represents relevant good practice for the calculation of extreme values for rainfall in the UK. In terms of climate change, Hitachi-GE has selected the upper estimate provided in the Environment Agency's publication which is based on UKCP09 climate projections. This has resulted in Hitachi-GE adding 40% to the values obtained from the FEH and FSR calculations to take into account climate change effects on extreme rainfall for the lifecycle of the plant. The resulting rainfall values are comparable to those calculated by other requesting parties for UK candidate sites. In my view, this represents an adequately conservative approach for GDA. It is of note that there is significant margin between the 10^{-4} GSE value of 308.7mm for the 24 hour duration rainfall and the Hitachi-GE design requirement for flood protection of 500mm above platform level. Based on all of the above, in my view Hitachi-GE's approach to the rainfall hazard is adequate.

Ice

59. Hitachi-GE has assessed the potential for the formation of frazil ice, rime ice and barrier ice within the Rainfall and Ice hazards group.

60. Hitachi-GE considered frazil ice within the Topic Report on the Generic Site Envelope (Ref.20), with the freezing point of seawater taken as the minimum seawater temperature in the GSE. Hitachi-GE found that frazil ice formation is possible for all candidate sites (with the exception of Hartlepool).

61. Barrier ice describes the formation of solid masses of ice within the sea. The extreme 10^{-4} /yr sea water temperatures defined in the GSE are lower than the general freezing point of seawater (-1.6 to -1.8°C dependent on salinity) which suggests that barrier ice could form. However, Hitachi-GE state that the temperatures provided are minimum daily temperatures and would not be maintained for sufficiently long periods to enable barrier ice to threaten the seawater inlet structures. This is due to the extended, sustained low temperature timescales required for barrier ice formation. Therefore Hitachi-GE does not consider barrier ice formation to be credible for the UK Generic site. I agree with this - however the argument would be better reinforced by identifying the depth of the intake heads and mixing rates to demonstrate a margin. I consider this to be a minor shortfall. Minor shortfalls are residual matters within GDA that are not considered serious enough to require specific action to be taken by the future licensee. Minor shortfalls are described further in section 4.7 of this document.

62. Hitachi-GE has assessed rime ice and has determined maximum ice thicknesses (with and without wind effects) for all candidate sites. The thickness of rime ice is calculated from Figure NA.2 of Eurocode EC3-3-1 (Ref.29) which demonstrates that ice thickness without wind effects is bounding. The GSE value was therefore set conservatively by excluding wind and a value has been selected which envelopes all of the 8 sites. The rime ice thickness for the GSE is:

- 10^{-2} 71.1 mm
- 10^{-4} 117.1 mm

63. I consider the assessments of all types of ice considered to be adequate for GDA. The methodologies used are standard and the conclusions reached are reasonable in line with the expectations of SAPs EHA.4 – Frequency of Initiating Event and EHA.11 – Weather Conditions.

4.2.2.4 DROUGHT

64. The drought hazard is not amenable to quantification but Hitachi-GE considers drought qualitatively and dismisses it from the GSE (Ref.30).

65. As the generic sites considered for the UK ABWR are all located in coastal areas, the low water level will be determined by the prevailing sea level – however, it is not possible to assess this in any meaningful way on a generic basis apart from stating that it will be bounded by LUHS in the fault schedule. As part of normal business at the site-specific phase, a potential licensee will need to consider whether low seawater levels could result in a plant trip (manual or automatic) or require a controlled manual shutdown due to plant limiting conditions.

66. I consider Hitachi-GE's approach to the drought hazard to be acceptable at GDA. However, the consideration of drought generally also includes a consideration of low rainfall level and lack of availability of water stocks and supplies. Low rainfall may also threaten foundation stability and underground systems such as pipes or electrical conductivity (lightning). It is not possible to consider these aspects in a meaningful way for a generic site and therefore consideration of drought due to low rainfall is deferred to the site specific phase. A future licensee will need to consider drought due to low rainfall as part of normal business.

4.2.2.5 SNOW

67. Due to limited and poor instrumental data availability, Hitachi-GE has considered snow by using Eurocode EC1-1-3 values in accordance with SAP EHA.2 – Data Sources (Ref.31). Hitachi-GE has defined a GSE value for snow of 1.50 kN/m2. This value is based on a Eurocode calculation only and does not account for climate change effects. I consider the use of a Eurocode value in place of a calculation using UK-specific data to be adequate for GDA due to the relatively low value of snow loading compared to that arising from vertical seismic inertial loading of the structural concrete roofs (Ref.11). However, this does not take into account secondary effects of snow, such as blockage of HVAC inlet vents which a future licensee will need to analyse on a site-specific basis as part of normal business. This is discussed further in paragraph 135 of this report.

68. I also consider the dismissal of climate change from the GSE value for snow to be adequate for GDA. Although UKCP09 does not provide probabilistic data for snow, it does state that there is a robust indication of significant reductions in snowfall given that the effects of climate change will generally cause warming of the climate (Ref.32). At the site-specific phase, further evidence will be needed to demonstrate that the increase in variance of extremes due to climate change is outweighed by the gradual increase in sea temperature. A future licensee will need to consider this as part of normal business.

4.2.2.6 ELECTROMAGNETIC INTERFERENCE (EMI)

69. The EMI hazard group consists of lightning and other EMI sources such as geomagnetic storms. These are considered separately below.

Lightning

70. As part of my Step 4 assessment, I noted that Hitachi-GE did not intend to provide a quantification of the lightning hazard as part of the GSE, and provided only a qualitative assessment of this hazard (Ref.33). I did not consider this to represent relevant good practice (RGP) and therefore raised a Regulatory Query (Ref.34) to request that Hitachi-GE provide a quantification of peak lightning strike intensity as part of the Generic Site Envelope definition. . Hitachi-GE agreed to quantify lightning density and intensity and proposed the use of UK Climate Projections 2009 (UKCP09) paper (Ref.35) for the eight candidate UK sites, and BS EN/IEC 62305 (Ref.36) respectively.

71. Hitachi-GE revised the Support Document on EMI for Generic Site Envelope (Ref.37) to include the agreed information. Based on my review of this document and subsequent discussions at L4 meetings (Refs.38,39), I raised a series of RQs (Refs.40,41) relating to the quantification of the lightning hazard. Hitachi-GE's proposed approach was to adopt a 200kA maximum lightning intensity based on BS EN/IEC 62530. However, in my view this did not meet the intent of the SAPs EHA. 11 and EHA. 4 (paragraph 242). My expectation was for Hitachi-GE to provide a GSE value based on the UK context rather than a code-based justification for the lightning strike intensity. Hitachi-GE had not provided any evidence to support the 200kA value as representing a bounding GSE value for the maximum lightning strike intensity at a 10^{-4} per year hazard level.

72. Hitachi-GE agreed to perform a further study on lightning intensity for the UK context and updated the associated documentation in line with the results of this study (Refs.42, 43). This study concluded that 300kA was representative of lightning strike intensity at the 10^{-4} per year hazard level for the UK context based on data from the International Council on Large Electrical Systems (CIGRE). Hitachi-GE also undertook scoping-level calculations which demonstrated no 'cliff-edge' effects in accordance with SAP EHA.7. Hitachi-GE noted that the actual margins would be site specific, and

dependent on the configuration of reinforcement-bars within the civil structures, which were to be used as the lightning protection system.

73. I am content with the use of 300kA lightning strike intensity for the GSE value. The study that Hitachi-GE performed is aligned with relevant good practice in terms of the use of UK-specific data and is consistent with lightning values determined by other requesting parties. I am therefore of the opinion that Hitachi-GE's treatment of the lightning hazard now meets RGP. However, I note that the support document (Ref.44) continues to make some limited reference to 200kA and could be interpreted as suggesting that it is reasonable for the electrical protection system to be designed in accordance with lightning protection level 1 (ie 200kA). This statement may cause confusion and I consider this to represent a minor shortfall in Hitachi-GE's safety case documentation. Minor shortfalls are residual matters within GDA that are not considered serious enough to require specific action to be taken by the future licensee. Minor shortfalls are described further in section 4.7 of this document.

Other Sources of EMI

74. Hitachi-GE has also considered other sources of naturally-occurring EMI from extreme space weather events including geomagnetic storms, solar radiation storms, and radio blackouts. Hitachi-GE considers that these hazards can have a significant effect on communication and power systems (Ref.44). The effects of extreme space weather events are likely to be widespread and could result in major disruption to the plants ability to respond to LOOP, and the ability of the outside world to provide support. Hitachi-GE's view is that in-depth treatment of these hazards should be considered during the detailed design phase. I consider this to be an adequate position for GDA. This is partially because the consideration of and protection against sources of EMI other than lightning requires choices that can only be made at the detailed design phase. It is also because consideration of these sources of EMI is a topic of current research and scientific advances made between the GDA phase and the site-specific phase could have a significant impact on the assessment of this hazard. Therefore I raise the following Assessment Finding:

75. Due to the requirement for detailed design information and due to developments in methods of assessment, a future licensee shall consider sources of naturally-occurring EMI from extreme space weather events including geomagnetic storms, solar radiation storms, and radio blackouts. This shall include an assessment of hazard magnitudes, frequencies, and potential effects, along with reasonably practicable resilience enhancements to protect against these hazards to reduce risks ALARP.

4.2.2.7 SEA OR RIVER WATER TEMPERATURE

76. Hitachi-GE undertook extreme value analysis to define sea water temperatures at the eight candidate UK sites. Seawater temperature is used in preference to river water temperature by Hitachi-GE as all of the eight UK candidate sites are coastal. The result is that Hitachi-GE define the GSE Design value for seawater temperature as (Ref. 20):

- Maximum Seawater Temperature
  - 10^{-2}/yr: 27.7°C
  - 10^{-4}/yr: 30.0°C
- Minimum Seawater Temperature
  - 10^{-2}/yr: -1.6°C

- 10^{-4}/yr: -1.9°C

77. For the maximum seawater temperature GSE value, the effect of climate change is considered up to 2080s based on the UKCP09 medium emissions scenario at the 84th percentile. For the minimum seawater temperature, climate change is not included since sea water temperatures are projected to increase as the climate changes. I consider this treatment of climate change to be adequate and conservative for the purposes of GDA. The resulting high and low seawater temperature are also adequate. The process undertaken to calculate them is in line with relevant good practice and the values are comparable to those selected by other requesting parties.

4.2.2.8 EXTERNAL FLOODING

78. At the beginning of Step 4, Hitachi-GE's submissions (Ref.21) stated that its design philosophy assumed a "dry site" as defined in SAP paragraph 261. At a dry site, all vulnerable structures, systems and components should be located above the level of the design basis flood, together with an appropriate margin. I considered this statement and judged that, within GDA, a dry site is not a realistic assumption for the GB context, as it is unlikely that all candidate sites within GB will meet the criteria. Therefore I requested that Hitachi-GE consider whether the UK ABWR could be adequately protected against external flooding if it were to be constructed on a non-dry site.

79. Hitachi-GE responded (Ref.45) to my request stating that it had performed a review and found that the UK ABWR could be protected from external flooding either by means of a dry site, or by permanent external barriers plus engineered features designed to prevent water intrusion and submergence and protect SSCs against consequential effects as part of defence-in-depth. Hitachi-GE's statement is based on protection measures against external flooding that are already present in the generic UK ABWR design or could be provided as part of detailed design at the site-specific phase depending on site context. Further information regarding the UK ABWR's resilience against external flooding was also provided in Hitachi-GE's response to RO-ABWR-0067 which I have assessed in section 4.2.4.1 below.

80. Based on Hitachi-GE's response to my query regarding the use of the "dry site" concept, Hitachi-GE's treatment of external flooding within GDA meets my expectations and is in accordance with SAP EHA.11 – Flooding. Although a dry site is preferred if reasonably practicable, a future licensee may decide to protect its site via permanent external barriers together with additional defence-in-depth flood protection measures. In this case, the future licensee will need to provide ONR with an ALARP submission demonstrating that raising the height of the platform to the dry site level would be grossly disproportionate. This will be performed by the future licensee as part of normal business.

4.2.2.9 SEISMIC ACTIVITY (EARTHQUAKE)

81. The Seismic Activity (Earthquake) group is made up of the following identified hazards:

- Dynamic Compaction (Earthquakes)
- Seismic Activity (Earthquake)
- Faults
- Liquefaction (Earthquake)

82. Hitachi-GE has also considered the following elements within the Seismic Activity (Earthquake) group:

- Minimum Shear Wave Velocity

83. Minimum Static Bearing Capacity

84. Hitachi-GE identifies, screens, and characterises the seismic activity hazard group in Chapters 2 and 6 of the PCSR (Refs.30, 46). Faults are stated in (Ref.47) to be a Site Licence phase activity. Chapter 2 of the PCSR states that Liquefaction is a site-specific hazard and is not assessed at GDA. I consider it appropriate to screen faulting and liquefaction out of consideration from GDA. It is not reasonable to expect the UK ABWR to be designed to withstand these hazards as that would likely incur prohibitive design and build costs, and as such they should be considered as part of site justification by a future licensee. In addition, the informed technical community is of the opinion that the capable faulting hazard is insignificant for UK sites. This view is supported by a substantial volume of qualitative data, however the nature of the data is such that transforming this into a quantitative demonstration is not practicable at a generic level. As part of licensing and examination of the supporting documents for the DCO this will be considered in more detail at a site specific level.

85. For Minimum Shear Wave Velocity, Chapter 2 of the PCSR refers the reader to (Ref.47) for the shear wave velocity values being considered at GDA. Minimum Shear Wave Velocity is not a specific hazard, although a low shear wave velocity might well create design problems such as amplified low frequency earthquake surface motion and soil structure interaction issues and be indicative of other hazards such as liquefaction. However, at GDA, Hitachi-GE is only considering rock or medium soils conditions, with best estimate and upper and lower bound values for shear wave velocity defined in (Ref. 47). Essentially, Hitachi-GE has decided that their GSE excludes sites with a low shear wave velocity, and I consider this reasonable for the purposes of GDA. A future licensee will be required to ensure that the site-specific minimum shear wave velocity is enveloped by the GSE value as part of normal business.

86. Minimum Static Bearing Capacity is stated, but it is apparent that for GDA, Hitachi-GE is only calculating demand bearing pressures for information only. For example, for the R/B, in Section 12.5 of (Ref.49), Hitachi-GE states, "For GDA, a factor of safety for bearing pressure will not be calculated as the allowable bearing pressure for a generic site has not been defined. Hence, the bearing pressure is calculated for information only and the calculated bearing pressure will be compared with the allowable bearing pressure during the site-specific stage." This is consistent with Chapter 2 of the PCSR, in which determination of appropriate bearing capacities are identified as a site specific activity. ONR's guidance to the requesting party on GDA (Ref.14) makes it clear that it is up to the requesting party to define a generic site envelope as broadly or as narrowly as it wishes. Therefore, it is not required that Hitachi-GE stipulates a generic bearing pressure in GDA. This is also consistent with the Civil Engineering workstream's conclusions on bearing capacity (Ref.50).

87. Chapter 2 of the PCSR does not discuss Dynamic Compaction in detail (although this hazard is listed against "Seismic Input" in PCSR Chapter 2). However, Dynamic Compaction (Earthquakes) is a structure-specific hazard. Hitachi-GE is adopting the GDA rock or medium soil conditions for the "formation layer" beneath structures, and are generally adopting the same properties for the "in-situ" layer up to ground level and for backfill around structures. Studies using softer material around and above service tunnels have also been included. Settlement and compaction issues are being addressed by the ONR Civil Engineering workstream (Ref.50). On this basis, Dynamic Compaction is not discussed further here.

88. During Step 3, the GDA seismic hazard definition required as part of the Generic Site Envelope was delayed due to it being based on the site-specific studies for the Wylfa Newydd site which required further justification and work. An RO was issued to cover this issue (RO-ABWR-0055: UK ABWR Generic Site Envelope - Seismic Hazard Definition). Due to the inconsistency between the GDA and site-specific resolution

programmes, Hitachi-GE decided to undertake the GDA seismic hazard definition as a separate exercise (Ref.51).

89. In Step 4 of GDA, Hitachi-GE defined DBEs and OBEs for the UK ABWR independently of the seismic analysis that remains ongoing at the Wylfa site. The methodology used was to review the UK Stress test reports to obtain UK seismic information at a variety of sites within Great Britain. Hitachi-GE developed a PGA for each soil type by using UHS PGA data from the eight candidate sites. Hitachi-GE excluded Bradwell from consideration since the PGA for Bradwell is disproportionately high compared to the other soft soil sites. Hitachi-GE defines seismic design spectra for hard soil and medium soil with 20% margins as GDA seismic design spectra. Hitachi-GE did not define a soft soil site, stating that the soft soil value was bounded by the medium soil spectra. Therefore, in my view, excluding Bradwell from consideration is reasonable.

90. Chapter 2 of the PCSR (Ref.30) states that the European Utility Requirement (EUR) hard soil spectrum anchored to 0.275g PGA and the EUR medium soil spectrum anchored to 0.25g PGA are both used at GDA for the horizontal motion for Seismic Category 1 SSCs, with a V/H ratio of 0.8 adopted for the vertical motion definition. This defines the DBE level for those SSCs required to withstand the 10^{-4}/yr hazard loading. Hitachi-GE states that the 10^{-3}/yr hazard loading is used for Seismic Category 2 SSCs and that the OBE is set at 10^{-2}/yr for any structure with a seismic classification and that this level may be used for Seismic Category 3 SSCs. This is discussed further in section 4.2.6 of this report.

91. RO-ABWR-0055 was closed by ONR letter (Ref.52) based on Hitachi-GE's submission of the Generic Site Envelope Seismic Design Spectra. The letter states that this submission "has been reviewed by ONR and we consider that it provides an adequate response to the Regulatory Observation." I agree with this conclusion.

92. Hitachi-GE states in (Ref.53) that if the proposed site has characteristics which lie outside the generic site envelope, the applicant will need to demonstrate by some other means that the proposed plant is acceptable at the proposed site. This may involve additional safety analysis and / or plant redesign. I consider this conclusion to be adequate and in line with my expectations.

4.2.2.10 LOSS OF OFFSITE POWER

93. Hitachi-GE has defined the following values for LOOP:

- Short term LOOP of 2 hours duration 5×10^{-2}/yr
- Medium term LOOP of 24 hours duration 5×10^{-3}/yr
- Long term LOOP of 168 hours duration 5×10^{-5}/yr

94. These values are based on the values set out by the ONR Fault Studies inspectors in RO-ABWR-0009 (Ref.54) as the values that would meet ONR's expectations. The result is that LOOP is considered as a frequent fault and so protection against it is included in the design basis, and this is in accordance with my expectations and the expectations of the Fault Studies inspectors. For further information on the assessment of Hitachi-GE's response to RO-ABWR-0009, see the Step 4 Fault Studies Assessment report (Ref.55).

4.2.2.11 ACCIDENTAL AIRCRAFT IMPACT

95. In the Topic Report on the Generic Site Envelope (Ref.20) Hitachi-GE states that accidental aircraft impact has a probability of annual exceedance less than 10^{-5} per annum for each ABWR structure, and is therefore considered a beyond design basis event. The strategy document for accidental aircraft impact assessment (Ref.56) is

based on UKAEA guidance (Ref.57), and uses UK aircraft crash statistics (Ref.58) and target area for each structure. The calculation comprises a number of conservatisms including airport proximity and unfavourable runway orientation. This is in line with the expectations of SAP EHA.8 – Aircraft Crash and supporting paragraph 249.

96. Malicious aircraft impact is treated deterministically as BDBE (Ref.59) and discussed further in the (Ref.50).

97. I reviewed the Aircraft Impact Assessment AIA Strategy document and subsequently raised a Regulatory Query (Ref.60), as I did not consider the document adequately demonstrated how risk mitigation strategies reduced accidental aircraft impact risk ALARP in accordance with the hierarchy of controls. In response, Hitachi-GE produced the document "AIA Strategy (Response to RQ-ABWR-0659)" (Ref.61). This states that load cases from accidental aircraft impact are bound by malicious events (see the Step 4 GDA Assessment Report for Civil Engineering (Ref.50) for assessment of load cases and consequences for the ABWR civil structures). The document "AIA Strategy (Response to RQ-ABWR-0659)" also describes the ABWR's engineered systems, segregation, redundancy and defence-in-depth that would enable safe shutdown. I consider that this document adequately demonstrates that risk mitigation strategies have been considered, and that risk from accidental aircraft impact is reduced ALARP.

4.2.2.12 EXTERNAL FIRE, EXTERNAL MISSILE, AND EXTERNAL EXPLOSIONS

98. Hitachi-GE has defined screening distance values (SDVs) for these hazards as follows:

- 2.5km (external fires and external missiles)
- 10km (external explosions)

99. These SDVs identify the distance from the plant at which an external hazard poses no credible threat to nuclear safety. Hitachi-GE has deferred detailed assessment of these hazards, over and above defining a SDV, to the site licensing phase.

100. I also note that the UK ABWR is designed to withstand internal fires (Ref.62) and jet fuel fires from aircraft crash (Ref. 50) and to withstand wind generated missiles (See Section 4.2.2.2).

101. ONR's SAPs do not explicitly cover the use of SDVs but the use of SDVs is aligned with the screening distance value approach set out in IAEA guidance (Ref.9). I consider Hitachi-GE's approach to be reasonable given the limitations of GDA and the requirement for site-specific information that would be needed to evaluate these hazards further and therefore it is accepted. SAP EHA.14- Fire, explosion, missiles, toxic gases etc – sources of harm states that sources that could give rise to fire, explosion, missiles, toxic gas release, collapsing or falling loads, pipe failure effects, or internal and external flooding should be identified, quantified and analysed within the safety case. It is not possible to identify the sources of these hazards for a generic design, as site specific information is required, and therefore a future licensee will need to consider these sources as part of normal business.

4.2.3 Combinations of Hazards

102. Hitachi-GE has produced a topic report on combined external hazards (Ref.63) to describe the methodology it has applied to identify and consider external hazards combinations. In my view, the methodology is in line with relevant good practice for the treatment of combinations of hazards. The events at Fukushima brought to light the fact that the state of practice in this area requires consideration via targeted research activities which are currently ongoing. In my view Hitachi-GE has considered combinations of hazards in a systematic and thorough manner and has adequately

considered recent developments in this area. However, I did identify some gaps in the methodology selected and its application which are described below.

103. Hitachi-GE's identification process of combined external hazards consists of three steps: 1) listing, 2) categorisation and 3) screening. The methodology and results are summarised in PCSR chapter 6 (Ref.46) and described briefly below.

104. Hitachi-GE's list of external hazards to consider in combination is taken from the document "Topic Report on External Hazard Protection" (Ref. 13) and consists of the 14 hazard groups screened into consideration in GDA. After listing hazard groups, Hitachi-GE then categorised external hazard combinations into three categories – consequential hazards, coincidental hazards and independent hazards which it defines as follows:

105. Combination Category I: Consequential Hazards

106. In this category, one hazard causes the other hazard to occur consecutively. As an example, a strong earthquake may cause a tsunami.

Combination Category II: Correlated Hazards

107. In this category, occurrences of the two events are not independent; both have a common cause or individual initiating event. For example, more than one hazard may be derived from the same meteorological conditions.

108. Combination Category III: Independent Hazards

109. In this category, occurrences of the two hazards are independent from each other. One hazard occurs and the second hazard occurs simultaneously or within a given period of time after the first hazard..

110. Hitachi-GE then applied a set of qualitative screening criteria in order to dismiss hazard combinations with a low overall impact or a low mean frequency of occurrence (i.e. below a 1x10-7 annual probability of exceedance). Screening is also performed for combinations that are bounded by similar events with the ABWR design basis. The qualitative screening arguments are based on expert input in line with relevant good practice, and in my view this has been effective for the most part. However the list of hazard groups feeding into the combinations as opposed to combinations of specific individual hazards may have been too simplistic. The result was that a common combination of high tide, storm surge and waves was overlooked using this methodology, and I raised two queries on this (Refs.64,65). These queries asked Hitachi-GE to consider the possibility of multiple combinations within a particular hazard group, and to review relevant good practice for combinations of hazards to ensure that all reasonable combinations had been considered. Hitachi-GE agreed and reviewed a variety of additional guidance documents including American Concrete Institute (ACI) 349-13 (Ref.66) and IAEA SSG-18 (Ref.67). As a result of this review, Hitachi-GE screened in the combination of extreme waves and sea water levels.

111. The Topic Report on Combined External Hazards has been revised in response to RQ-ABWR-1171 (Ref.68). This RQ asked Hitachi-GE to take into account the fact that the mission time used to calculate external hazard combinations should be based on the duration of the consequences of the event and not the hazards duration (Ref.69).

112. I have considered the full list of combinations of hazards including the methodology applied to their derivation. Hitachi-GE has applied a reasonable methodology and has compiled a complete list of combinations of hazards based on both expert judgment and in accordance with international and national guidance documents. The resulting list is reasonable and in line with SAPs EHA.6 – Analysis. Therefore, I judge that

Hitachi-GE's consideration of combinations of hazards is reasonable for GDA. However, the list should be fully reviewed on a site-specific basis to ensure that all combinations of hazards that could affect a particular site have been taken into account. Therefore I make the following Assessment Finding:

113. **As a result of the assumptions made in GDA, a future licensee shall review the combinations of hazards at the site-specific stage ensure that all reasonably foreseeable combinations of hazards for a specific site have been included in the analysis.**

4.2.4 Post-Fukushima Lessons Learnt – Beyond Design Basis Hazards

114. The Hitachi-GE UK ABWR entered GDA after the events at Fukushima had occurred, and Hitachi-GE had already applied lessons learnt to the generic design, resulting in a number of safety enhancements. These enhancements focused on further prevention of SBO (Station Blackout) and LUHS (Loss of Ultimate Heat Sink), ensuring water supply to the reactor, pressure vessel integrity, and maintenance of the SFP (Spent Fuel Pool) water level. These additional layers of defence in depth increase the robustness of the ABWR design against extreme external events, including external flooding.

115. As part of its GDA assessment, assessors in the Fault Studies discipline raised Regulatory Observation (RO-ABWR-0039) entitled "UK Learning from the Fukushima Dai-ichi Events" (Ref.70). This RO required Hitachi-GE to respond to the ONR Chief Inspector's Recommendations, to the European stress test reports and to the IAEA's observations and lessons. Hitachi-GE's overall response is considered in the assessment report for that discipline (Ref.55).

116. I considered Hitachi-GE's response to RO-ABWR-0039 from an external hazards perspective and found that it was not adequate for the external hazards topic area. Specifically, when the UK ABWR entered Step 4 of GDA its external hazards submissions did not include a consideration of beyond design basis hazards. This did not meet my expectations and was not resolved by the response to RO-ABWR-0039. I therefore raised an RQ (Ref.71) and, subsequently, another Regulatory Observation (RO-ABWR-0067) (Ref.72) entitled "UK ABWR Generic Site Envelope – External Flooding and Beyond Design Basis Events." In summary, this RO required Hitachi-GE to provide the following:

- A Beyond Design Basis (BDB) evaluation for external flooding and further information on the UK ABWR's robustness including consideration of the effects of flooding scenarios at several different elevations
- A description of the process used to evaluate beyond design basis margins for all external hazards considered in GDA

117. I discuss Hitachi-GE's responses to both of these points below, starting with external flooding.

4.2.4.1 BEYOND DESIGN BASIS EXTERNAL FLOODING

118. Hitachi-GE's response to RO-ABWR-0067 (Ref.45) postulated an extreme (beyond design basis) external flooding event in which sufficient flood water entered the Heat Exchanger Building and transformer building to result in Loss of Ultimate Heat Sink and Loss of Offsite Power. Hitachi-GE then identified SSCs (Systems, Structures and Components) that would be credited to achieve the fundamental safety functions and allow the reactor to remain in a stable condition in hot standby. These SSCs were reviewed and their vulnerability to external flooding was assessed. Hitachi-GE did this by defining a critical external flood height for each flooding scenario. The critical

external flood height is the lowest value of critical external flood height for each SSC identified and is the height at which components would fail if immersed in water.

119. The result of this review was that Hitachi-GE identified a number of potential design enhancements that could be implemented depending on the characterisation of external flood risk that will be derived at the site-specific phase. This derivation will include an assessment of whether the site meets the criteria of a dry site, or whether permanent external barriers are sufficient to reduce risks ALARP. The potential design enhancements include appropriate water sealing or elevation of the Heat Exchanger Building and transformer, Reactor Building, Control Building, Electrical Diesel Generator Buildings, and Backup Building (B/B). Hitachi-GE also states that all main doors will be located at least 500mm above platform level. However, the exact height of openings will be determined at the site-specific assessment stage.

120. In my view, this response is adequate for the purposes of GDA. External flooding levels and occurrence frequencies are highly dependent on site-specific conditions. Therefore the potential for external flooding to affect a nuclear installation can only be fully evaluated at the site-specific phase when the platform height is known and the external flooding hazard to the site has been evaluated. Nonetheless, it is important, at the GDA stage, to understand the potential vulnerabilities to external flooding that are present in a generic design, to ensure that these vulnerabilities do not contribute excessively to the flood risk. Hitachi-GE has demonstrated this. The identification of potential vulnerabilities by Hitachi-GE will provide crucial information to future licensee as to how best protect the generic design against an extreme flood event. However, details regarding resilience requirements against external flooding will be finalised at the site-specific stage.

121. Therefore, I make the following Assessment Finding:

122. As a result of the assumptions made in GDA, a future licensee shall consider and implement adequate water sealing and/or elevation of the Heat Exchanger Building and transformer, Reactor Building, Control Building, Electrical Diesel Generator Buildings, and Backup Building. The determination of requirements shall be based on site-specific evaluation of external flooding beyond the design basis in accordance with the principles of ALARP.

4.2.4.2 SEISMIC AND OTHER BEYOND DESIGN BASIS HAZARDS

123. Hitachi-GE has produced the report “Cliff Edge Effects on Civil Engineering” (Ref.73) in response to RO-ABWR-0067, stating that for most external hazards, the safety functions of UK ABWR are protected by the civil structures. I agree with this statement, as the civil structures provide the main protection against significant external hazards by providing a support function and a barrier function.

124. Hitachi-GE’s document “Cliff Edge Effects on Civil Engineering” summarises the screening and analysis methodology and results of Hitachi-GE’s review of cliff edge effects on a selection of civil engineering structures. The list of external hazards considered in this report is as follows:

- Air Temperature
- Wind
- Rainfall & Ice
- Snow
- Seismic Activity
- External Missile (Tornado missiles)

125. External explosions and external missiles (apart from tornado missiles) are not included in the report, as they are considered in GDA only in terms of screening

distance values. This will be confirmed at the site-specific phase. Accidental aircraft impact is bounded by malicious aircraft impact. Beyond design basis margins for external flooding were considered in a separate report (Ref.45). In my view, Hitachi-GE's selection of external hazards for consideration of beyond design basis effects is adequate. ONR's guidance to requesting parties (Ref.14) states that "the definition of the site envelope can be as broad or narrow as the RP wishes", and that "the sensitivity of the design to the magnitude of external hazards should be well understood." Hitachi-GE has selected those external hazards for consideration that are most likely to have a detrimental effect on SSCs beyond the design basis. Other external hazards, such as high or low seawater temperature and drought, are likely to cause predominantly operational issues, or to be bounded by other faults such as LUHS. These hazards should be considered at the site-specific phase to determine whether there are any cliff-edge effects by a future licensee as part of normal business.

126. I queried Hitachi-GE's selection of structures included in an earlier draft of its report "Cliff Edge Effects on Civil Engineering" as the reasons behind the selection of the representative structures were not clear. I also asked Hitachi-GE to include the EDG buildings in its cliff-edge effects analysis. This is because the EDG buildings provide defence in depth against beyond design basis hazards. In addition, Hitachi-GE proposes that the EDGs be housed in separate buildings external to the reactor building which differs from previous ABWR designs.

127. Hitachi-GE has included the EDG buildings in a subsequent revision of the report and has also provided further details addressing the reasons behind the selection of structures. Hitachi-GE has considered cliff-edge effects on structures housing Class 1 SSCs as the first-line means of protection against Design Basis faults. It has also considered cliff-edge effects on structures housing Class 2 SSCs as countermeasures against severe accidents. Therefore I consider that Hitachi-GE has adequately addressed my comments.

<u>Seismic Hazard</u>

128. Hitachi-GE has produced the report "Seismic Evaluation Methodology for Cliff-edge Effect on Civil Structures" (Ref.74). This report is a methodology document in which Hitachi-GE sets out its strategy for demonstrating the absence of cliff-edge effects on seismic category 1, 1A, and 2 structures. The document has been assessed by ONR's civil engineering inspectors as part of the civil engineering work stream (Ref.50) Their conclusion is that Hitachi-GE's methodology is adequate.

129. Hitachi-GE has also undertaken seismic fragility analysis in support of a seismic PSA during GDA, and this work has been assessed by the PSA (Probabilistic Safety Analysis) topic stream (Ref 24). The PSA team has judged this analysis work as adequate.

130. Hitachi-GE states within the report "Cliff Edge Effects on Civil Engineering" (Ref.73) that it has assessed load paths for ductile failure and has undertaken seismic margins assessment to calculate reserve capacities. Hitachi-GE states that with the significant safety factors inherent in the design, there is an adequate margin of reserved capacity above the generic site envelope values. In order to demonstrate these margins, Hitachi-GE has calculated the ground acceleration with 10% probability of each structures' failure, and determined that it is greater than 1.5 x DBE. This satisfies the criterion defined in "Seismic Evaluation Methodology for Cliff-edge Effect on Civil Structures" and judged as adequate by the ONR civil engineering inspectors. This criterion states:

- "Less than about 10% probability of unacceptable performance for a ground motion equal to 150% of the DBE ground motion".

131. Therefore, Hitachi-GE concludes that there is no cliff-edge in the seismic design. I agree with this conclusion. It is in accordance with ONR SAP EHA.18 – "Beyond design basis events" and paragraph 246 as Hitachi-GE has performed an analysis of fault sequences beyond the design basis, confirmed the absence of 'cliff edge' effects just beyond the design basis. For each seismic category 1, 1A, and 2 structure it has identified the margins at which the safety functions could be lost. And it has used this information to inform the PSA and severe accident analysis. Therefore I judge Hitachi-GE's consideration of beyond design basis seismic hazards to be adequate.

132. Hitachi-GE has performed SMA (seismic margins assessment) and seismic fragility assessment as part of GDA. The results of these assessments are considered in the PSA assessment report (Ref 24).

Other Beyond Design Basis Hazards

133. For other hazards, Hitachi-GE has stated that its basic philosophy is that beyond design basis events will, for the most part, be bounded by the seismic hazard (Ref.46).

134. I queried (Ref.75) how potential cliff edge effects of meteorological hazards that are not bounded by seismic hazards would be identified and captured. I requested a summary of the approach used to address the BDB design margins for extreme high and low temperature as one example of a meteorological hazard whose effects are not related to and would therefore not be bounded by the seismic hazard. Hitachi-GE responded by providing a document (Ref.76) summarising the data presented in (Ref.77). This document clearly describes the proposed design envelope and states that there is considerable margin for both high and low air temperatures based on the differences between allowable indoor and outdoor design temperatures and on the time available before outdoor air temperatures would affect indoor air temperatures. I consider this an adequate position for the purposes of GDA, recognising that ambient air conditions for the HVAC design will undergo a comprehensive review in the site specific phase during the detailed design stage as part of normal business.

135. I also queried (Ref.75) Hitachi-GE's methodology for considering snow and wind effects as being bounded by the seismic load, since a seismic analysis incorporating damping and ductility may not be relevant to a wind or snow analysis. Hitachi-GE responded (Ref.78) by performing an internal review which resulted in Hitachi-GE adding two additional considerations – these are the blockage of an HVAC inlet due to snow and blockage of a water inlet due to ice. Hitachi-GE states that protection against effects such as blockage of intakes, is provided by that plant having backup systems commensurate with the plant safety category and class. Again, I consider this position adequate for GDA but will need further consideration as part of normal business during the site-specific detailed design phase.

136. Hitachi-GE considers wind-induced building damage to be bounded by the seismic hazard. I consider this claim reasonable for the majority of buildings within the GDA scope, but I considered the R/B stack as a special case. This is because the R/B stack is a light structure with a large "sail" face and therefore I considered that the seismic load case may not be bounding in this instance. I checked Hitachi-GE's document "Civil Engineering Supporting Report – Stack Structural Design Report" (Ref.79) which confirms that seismic loads dominate and includes a section on beyond design basis considerations. Therefore, I accept Hitachi-GE's claim that the seismic hazard bounds the extreme wind loading hazard for buildings within the scope of GDA. Comprehensive assessments of the structural design reports for those buildings with the scope of GDA have been performed by the civil engineering inspectors as reported in the civil engineering Step 4 GDA assessment report (Ref.50).

137. I consider Hitachi-GE's basic philosophy that beyond design basis events will, for the most part, be bounded by the seismic hazard to be adequate for the purposes of GDA. However, if site-specific seismic analysis demonstrates that the generic site envelope's seismic hazard definitions are not bounding then this strategy will be undermined. Therefore I make the following Assessment Finding:

138. As a result of assumptions made concerning BDB hazards in GDA, a future licensee shall consider whether or not the site-specific seismic analysis demonstrates that the generic site envelope's seismic hazard definitions are bounding. If the generic site envelope's seismic hazard definitions are not bounding, a future licensee shall assess the vulnerabilities of the UK ABWR to beyond design basis hazards assumed in the generic design to be bounded by generic site envelope seismic hazard definitions.

139. In terms of tornado missiles, in my view, Hitachi-GE demonstrates (Ref.80) that considerable margin exists in the ABWR civil structures design when compared with the NUREG 0800, Standard Review Plan (Ref.81) for preventing tornado missile damage. The minimum thickness values for the ABWR GDA design's wall and roof are 600mm and 300mm for the walls and roof respectively, at 35 MPa concrete strength, which compares with minimum acceptable thicknesses of 267mm and 196mm for the same strength concrete given in the US NRC Standard Review Plan. I consider this adequate and conservative for the purposes of GDA.

4.2.5 External Hazards Safety Analysis

140. Hitachi-GE has analysed the potential effects of external hazards on the UK ABWR by performing design basis analysis (DBA) and probabilistic safety analysis (PSA).

Design Basis Analysis

141. Hitachi-GE has presented the process it used to develop the UK ABWR Fault Schedule in Chapter 24 of the PCSR entitled "Design Basis Analysis" (Ref.82). Hitachi-GE's approach to design basis analysis is assessed in the Fault Studies Assessment Report (Ref.55). However, I have assessed the sections of the Topic Report on Fault Assessment (Ref.83) that are directly relevant to the external hazards discipline.

142. Potential EH Initiating Events and the Fault Schedule

143. As part of its design basis analysis, Hitachi-GE has considered potential initiating events for all 14 external hazards that are in scope for GDA. It has also considered "Water Based Biological Fouling" as an initiating event for the UK ABWR. Water-based biological fouling was screened out of GDA as site-specific information is needed to assign a frequency to this hazard. However, Hitachi-GE has included it as an initiating event in the fault schedule due to OPEX which demonstrates that this is an important external hazard. Hitachi-GE has therefore taken what is in my view a conservative decision to consider it at the GDA stage, and I welcome this approach.

144. For each potential initiating event, Hitachi-GE has evaluated plant behaviour by examining the resulting fault sequences and has then defined the safety functions needed to mitigate or recover from the consequences. Then, Hitachi-GE has grouped initiating events based on similar fault sequence and demands on safety functions during the event sequence progression. Based on this review of the UK ABWR's capacity to withstand external hazards, Hitachi-GE has concluded that two external hazards groups are required to be listed on the fault schedule. The two external hazard groups on the UK ABWR fault schedule (Ref.83) are seismic hazards and biological fouling. Biological fouling is considered a frequent fault and is bounded by LUHS (loss of ultimate heat sink) in both operating and shut-down modes.

145. SAP ESS.11 supporting paragraph 407 states that "a fault schedule (sometimes known as a safety schedule or a fault and protection schedule) should be provided to link faults, fault sequences and safety measures." ONR's fault studies inspectors note in their assessment of the UK ABWR fault schedule that only those hazards that cannot be bounded by other events have been taken forward for DBA and inclusion on the fault schedule, and this approach has been accepted by the ONR fault studies inspectors (Ref.55). I agree with their conclusions. However, given Hitachi-GE's decision to include only two external hazard groups on the fault schedule, further information demonstrating connecting external hazards load definitions to plant effects and protection measures was required, and this is discussed below.

146. Fundamental Safety Functions, External Hazard Groups and Plant Effects

147. Hitachi-GE has defined a set of fundamental safety functions (FSFs) which must be met by the UK ABWR at all times. These are then broken down into sets of High Level Safety Functions (HLSFs). Each Safety Functional Claim (SFC) made in the PCSR is then linked to one of these HLSFs. This approach has been assessed by the ONR Fault Studies inspectors who judged that Hitachi-GE has adequately identified appropriate safety functions at both the FSF and HLSF level, in accordance with SAP EKP.4 (Ref.55).

148. Within the external hazards discipline, Hitachi-GE submitted a Topic Report on External Hazards Protection (Ref.13) in order to demonstrate that SSCs are designed to withstand the identified generic external hazard conditions and combinations as appropriate to their safety classifications. At the beginning of Step 4, I noted (Ref.84) that the links between external hazards and protection of SSCs were not clear in the documentation. My review of the safety case submissions revealed that the narrative connecting external hazards load definitions to plant effects and protection measures was not evident. I also noted that evidence was not always referenced to back up claims and arguments made in PCSR chapter 6 on external hazards protection. I therefore requested further information from Hitachi-GE summarising the way that the UK ABWR is designed to prevent external hazards from causing initiating events and demonstrating that adequate protection against them has been provided.

149. Hitachi-GE stated that the lack of a consistent narrative at the beginning of Step 4 was due to the fact that during Step 3 of GDA, there was not a complete list of HLSFs (High-Level Safety Functions) identified that were appropriate for external hazards (Ref.84). Hitachi-GE has now added additional HLSFs (including for example HLSF 5-17 – "Function to provide structural support to SSCs"). I have reviewed the list of HLSFs provided in Step 4 and in my view they now capture the required safety functions and provide a clear and complete list that is in line with my expectations.

150. The Topic Report on External Hazards Protection now identifies the HLSFs that are relevant to external hazards. These HLSFs are then linked to hazard groups and their plant effects are then described. The plant effects include a hazard definition, a description of potential vulnerabilities, and a consideration of combinations of hazards. The Topic Report links external hazards and potential plant effects with the high level safety functions that the SSCs are designed to maintain. References are also provided to the engineering chapters of the PCSR where further information on the protection measures against each plant effect is given.

151. External Hazards Initiating Events Table

152. Given Hitachi-GE's decision not to include all external hazards initiating events on the fault schedule, my expectation in Step 4 was that Hitachi-GE would provide a separate summary table giving clear and concise information on hazards protection for those hazards that are not listed on the fault schedule in accordance with the requirements of

SAP FA.8 which requires a clear and auditable linking of initiating faults, fault sequences and safety measures.

153. In response to my request for this information, Hitachi-GE produced a comprehensive table entitled “External Hazards Initiating Events” that provides a useful high level overview linking hazard groups to initiating events. The table includes plant effect groups and identifies the high level safety functions that Hitachi-GE considers as being relevant to external hazards. For all hazard groups apart from seismic, the table lists initiating events and consequences and provides links to the PCSR chapters where mitigating or safety features that protect against these hazards are described.

154. The External Hazards Initiating Events table links each consequence to HLSFs, SFCs, and SPCs. This is in line with the requirements of SAP FA.8 which requires a clear and auditable linking of initiating faults, fault sequences and safety measures and it meets my expectations. I consider that the External Hazards Initiating Events table meets the equivalent requirements of the fault schedule from an external hazards perspective.

155. I selected a sample of initiating events and traced these through the safety case. I selected the sample on the basis of either the wide-spread nature of the consequences of failure (for example, structural load on civil structures) or the proportion of the contribution to CDF (core damage frequency) (for example, cooling and ventilation). For these initiating events, I examined the External Hazards Initiating Events table and traced the HLSFs listed in the table to the relevant PCSR chapters where the requirements on the SSCs are specified. I found that they were indeed present in the chapters as specified in the table. Therefore I conclude that Hitachi-GE has followed a systematic, auditable, and comprehensive process to identify faults arising from external hazards and the requirements for their protection against potential vulnerabilities in accordance with the expectations of SAP FA.8 - Linking of initiating faults, fault sequences and safety and SAP ESS.11 – Demonstration of adequacy.

156. Conclusion

157. Hitachi-GE has considered all external hazards within the scope of GDA as potential initiating events in accordance with SAP EHA.1 – “Identification and Characterisation” and supporting paragraph 231 and has analysed the effects of these potential initiating events on the UK ABWR in accordance with SAP EHA.6 – Analysis. As part of normal business, the external hazards that were not included in the GDA scope but that could affect the safety of the facility will need to be analysed. External hazards whose site-specific values are not bounded by the GSE values will also need further analysis at the site-specific phase as part of normal business.

158. As stated in section 2.3, the ability of an SSC to deliver its safety functions during normal operations (including for shutdown), fault sequences and accident conditions with adequate consideration of external hazards loads are considered in the systems chapters of the PCSR and assessed by the relevant engineering specialisms.

<u>Probabilistic Safety Analysis</u>

159. Hitachi-GE has described the PSA for the generic design of the UK ABWR in Chapter 25 of the PCSR entitled “Probabilistic Safety Analysis.” This has been assessed by the ONR PSA specialist inspectors, including those aspects of the PSA relevant to external hazards. This assessment has been performed in collaboration with myself as the external hazards specialist inspector but is reported in the PSA Step 4 assessment report (Ref.24). The conclusions of the assessment are summarised here briefly for information.

160. The ONR PSA inspectors have considered the screening and prioritisation of external hazards as part of their review of the Hitachi-GE PSA. Their conclusion is that whilst the analysis performed for GDA is comprehensive and well documented Hitachi-GE's analysis is generic and defers consideration of a number hazards to the site specific phase. Therefore, prioritisation and assessment of external hazards should be re-done after GDA, taking site specific characteristics into account. I agree with this conclusion. It is to be expected that a number of external hazards would be deferred to the site-specific phase as meaningful analysis of these external hazards cannot be performed without site-specific data.

161. In terms of the generic design being considered within GDA, the PSA inspectors conclude that sufficient evidence, proportionate to this stage of the project, is presented to understand the risk profile of the UK ABWR due to external hazards. I agree with this conclusion. The PSA performed for external hazards is in line with the expectations set out in SAP paragraph 246 which states that the analysis of beyond design basis events should "provide an input to probabilistic safety analysis of whether risks targets are met."

162. Further work will be needed at the site-specific phase, as part of normal business and once site-specific hazard magnitudes have been analysed, to ensure that safety is balanced so that no single type of hazard makes a disproportionate contribution to overall risk in line with ONR SAP EHA.18 – "Beyond design basis events" and paragraph 246. This work will be performed by a future licensee as part of normal business.

4.2.6 Seismic Categorisation

163. The seismic hazard group is treated differently from other hazards in terms of its categorisation methodology. This is due to the wide-ranging potential effects of an extreme seismic event, and Hitachi-GE describes the treatment of the seismic hazard in Chapter 5.4 of the PCSR (Ref.85. Seismic hazard effects may have widespread impact across the whole plant. Therefore Hitachi-GE determines seismic load effects according to seismic categories.

164. Each SSC is assigned to a seismic category that corresponds to the consequences of failure, either in terms of any requirement on the SSC to provide its safety function during and following a seismic event or in terms of radiological dose (both on-site and off-site consequences) in case of the SSC failing due to the seismic event.

165. Hitachi-GE has defined the following seismic categories:

Seismic Category	Definition
1	Seismic Category 1 SSCs are designed to withstand the DBE, i.e. an earthquake with probability of exceedance 10^{-4} estimated on a conservative basis, and are required to maintain structural and functional integrity in combination with other appropriate loads.
2	Seismic Category 2 SSCs are designed to withstand an earthquake with probability of exceedance 10^{-3} estimated on a conservative basis and are required to maintain structural and functional integrity in combination with other appropriate loads.

3	Nuclear safety related SSCs that are not categorized as Seismic Category 1 or 2 are designated as Seismic Category 3.

166. The terminology used by Hitachi-GE to define seismic categories is non-standard. As set out in ONR TAG 94 (Ref.86), relevant good practice is to assign categories to safety functions and classifications to SSCs. Hitachi-GE has followed this approach for non-seismic related categorisation and classification. However, Hitachi-GE does not use the terminology "seismic classification" and instead assigns categories to SSCs depending on the seismic withstand requirements. I consider this approach to be adequate as Hitachi-GE has applied its chosen terminology in a logical manner and has explained its methodology clearly.

167. I queried (Ref.87) the way that Hitachi-GE intended to consider its approach to seismic categorisation of SSCs which do not have a direct role in delivering safety functions following a seismic event, but whose failure could have consequential interactions or effects on those SSCs that do have a role to perform. Hitachi-GE updated PCSR Chapter 5 (Ref.85) to identify Seismic Category 1A SSCs as follows:

Seismic Category	Definition
1A	Seismic Category 1A SSCs are designed to withstand the DBE, i.e. an earthquake with probability of exceedance 10^{-4} estimated on a conservative basis, in combination with other appropriate loads without spatial interactions or any other interactions with Seismic Category 1 SSCs.

168. This is in line with ONR SAP ELO.4 paragraph 206, which states that any interactions between a failed SSC and other SSCs should be minimised.

169. Seismic category 1, 1A, 2 or 3 is assigned to each SSC depending on the consequences of failure. These consequences take into account requirements on the SSC to provide its safety function during and following a seismic event as well as radiological dose (including on-site / off-site consequences). Category 1 is assigned to SSCs necessary to ensure the capability to prevent or mitigate the consequences of seismic events which could result in a potential onsite unmitigated dose consequence >200mSv or offsite unmitigated dose consequence >10mSv evaluated on a conservative basis. Category 1 is also assigned to SSCs which are required in the event of a beyond design basis accident which contains a seismic event as part of its fault sequence. Category 2 is assigned to SSCs necessary to prevent or mitigate the consequences of seismic events which could result in a potential onsite unmitigated dose consequence >20mSv or offsite unmitigated dose consequence >1mSv evaluated on a conservative basis. As stated above, nuclear safety related SSCs that are not categorized as Seismic Category 1 or 2 are designated as Seismic Category 3

170. Chapters 2 and 5 of the PCSR (Refs. 30 and 85) clearly describe Hitachi-GE's system for identifying seismic categories for SSCs. Hitachi-GE has applied the 10^{-4}/yr hazard definition as described in the Generic Site Envelope section of this report to Seismic Category 1 SSCs. This defines the DBE level for those SSCs required to withstand the 10^{-4}/yr hazard loading in line with the intent of SAP EHA.9 applied proportionately to the GDA assessment phase. It is also in line with SAP FA.5 on Initiating Faults. Although SAP EHA.9 states that "the seismology and geology of the area around the site and the geology and hydrogeology of the site should be evaluated to derive a

design basis earthquake (DBE)", consideration of the attributes of the area around the site must clearly be deferred to the site-specific phase.

171. Hitachi-GE states that the $10^{-3/}$yr hazard loading is used for Seismic Category 2 SSCs and that the OBE is set at 10^{-2}/yr for any structure with a seismic category and that this level may be used for Seismic Category 3 SSCs. This is in line with the expectations of SAP EHA.9 paragraph 254 which states that an operating basis earthquake (OBE) should also be determined.

172. I have considered Hitachi-GE's methodology for seismic categorisation of SSCs. Hitachi-GE has applied a reasonable methodology that meets my expectations. The methodology is clearly explained, is logical, and enables buildings, structures and plant in the facility to be designed to withstand safely the ground motions involved in line with the expectations of SAP EHA.9. Consideration of the application of the seismic design load to the SSCs is part of the civil engineering workstream. This is discussed in the Civil Engineering assessment report (Ref.55).

4.3 Regulatory Observations

173. A Regulatory Observations (RO) is raised when ONR identifies a potential regulatory shortfall which requires action and new work by the RP for it to be resolved. Each RO can have several associated actions. Two ROs were raised in the external hazards area as part of GDA:

174. RO-ABWR-0055. During Step 3 of GDA, the seismic hazard definition required as part of the Generic Site Envelope was delayed due to it being based on site-specific studies for the Wylfa Newydd site, which required further justification and work. An RO was raised to cover this issue (RO-ABWR-0055: UK ABWR Generic Site Envelope - Seismic Hazard Definition). Due to the inconsistency between the GDA and site-specific resolution programmes, the GDA seismic hazard definition was carried out as a separate exercise during Step 4 of GDA. My assessment of Hitachi-GE's response to this RO is in section 4.2.2.9 of this report. The RO was closed by letter (Ref.52) and no assessment findings or shortfalls resulted.

175. RO-ABWR-0067. My assessment of Hitachi-GE's Step 3 GDA submissions in relation to external hazards identified shortfalls in respect of the treatment of beyond design basis assessment of external hazards generally, and external flooding specifically. During Step 4 of GDA, I raised Regulatory Observation (RO-ABWR-0067) entitled "UK ABWR Generic Site Envelope – External Flooding and Beyond Design Basis Events." Further work was required for Hitachi-GE to address this justification issue and to provide evidence during GDA step 4 that there is no residual safety issue. My assessment of Hitachi-GE's response to this RO can be found in section 4.2.4 of this report. The RO was closed by letter (Ref.88) and no shortfalls resulted. I made one assessment finding relating to the need for a future licensee to consider on site flood protection measures, which is described in section 4.2.4.1 of this report.

176. A summary of ROs related to external hazards can be found in Annex 4.

4.4 Comparison with standards, guidance and relevant good practice

177. ONR's SAPs were reviewed post-Fukushima after ONR's Chief Nuclear Inspector's report on the Implications of the Fukushima events on the GB nuclear industry was published. That report concluded that there were no significant gaps in the SAPs but recommended a review to ensure lessons learnt were incorporated. The review resulted in a number of changes to the SAPs which were reissued in 2014.

178. Hitachi-GE's submissions in external hazards have been assessed against the 2014 SAPs and meet ONR expectations. I have made considerable efforts over Step 4 to

ensure that the RP is fully aware of ONR's SAPs expectations and this has been reflected in the design and quality of the submissions. The SAPs have had a major impact on the development of the external hazards generic site envelope and in demonstration of adequate external hazards analysis and protection measures.

179. ONR's document "Guidance to Requesting Parties" (Ref.14) sets out ONR's expectations to requesting parties with regard to the GDA process for the safety and security assessment of nuclear power stations intended for construction and operation in Great Britain. It provides high-level guidance on relevant good practice for the consideration of external hazards and the generic site envelope within GDA. I have assessed Hitachi-GE's submissions against the expectations set out in this guidance and in my view the submissions are in line with the guidance provided.

180. I consider that, from an external hazards perspective, the use of the latest internationally recognised and accepted nuclear-specific codes and standards has led to a conservative design commensurate with the importance of the safety function(s) being performed. These codes and standards reflect relevant good practice to a level appropriate to GDA.

4.5 Overseas regulatory interface

181. ONR has formal information exchange agreements with a number of international nuclear safety regulators, and collaborates through the work of the International Atomic Energy Agency (IAEA) and the Organisation for Economic Co-operation and Development Nuclear Energy Agency (OECD-NEA). This enables ONR to utilise overseas regulatory assessments of reactor technologies, where they are relevant to the UK. It also enables the sharing of regulatory assessment findings, which can expedite assessment and helps promote consistency.

182. ONR also represents the UK on the Multinational Design Evaluation Programme (MDEP).This seeks to:

- Enhance multilateral co-operation within existing regulatory frameworks
- Encourage multinational convergence of codes, standards and safety goals
- Implication of MDEP products in order to facilitate the licensing of new reactors, including those being developed by Gen IV international Forum

183. Within the external hazards workstream, extensive engagement with international regulators has taken place as part of MDEP. The UK led the drafting of the MDEP common position paper (Ref.89) which has been published on the OECD/NEA website. The paper addresses key issues related to the Fukushima Dai-ichi Nuclear Power Plant Accident. The national regulatory authorities from Japan, Sweden and the United States also participated in developing the common position.

184. The main conclusion of the MDEP common position paper relevant to the external hazards workstream is that the accident at the Fukushima Daiichi NPP has reinforced the need to undertake, as part of the safety review process for ABWRs, a comprehensive analysis of external hazards. This should include a consideration of relevant combinations of events. My assessment of Hitachi-GE's submissions for GDA has determined that they are fully consistent with the recommendations and conclusions of the MDEP paper for external hazards as appropriate for GDA. Further work will be needed as part of the site-specific phase in order to demonstrate that the MDEP recommendations have been fully implemented for the UK ABWR from an external hazards perspective, as design basis events can only be determined by considering the site hazard characteristics.

4.6 Assessment findings

185. During my assessment, five residual matters were identified for a future licensee to take forward in its site-specific safety submissions. Details of these are contained in Annex 5.

186. These matters do not undermine the generic safety submission and are primarily concerned with the provision of site specific safety case evidence, which should become available as the project progresses through the detailed design, construction and commissioning stages. These items are captured as assessment findings.

187. I have recorded residual matters as assessment findings if one or more of the following apply:

- site specific information is required to resolve this matter;
- resolving this matter depends on licensee design choices;
- the matter raised is related to operator specific features / aspects / choices;
- the resolution of this matter requires licensee choices on organisational matters;
- to resolve this matter the plant needs to be at some stage of construction / commissioning.

188. Assessment Findings are residual matters that must be addressed by the Licensee and the progress of this will be monitored by the regulator.

4.7 Minor shortfalls

189. During my assessment two residual matters were identified as minor shortfalls in the safety case, but are not considered serious enough to require specific action to be taken by the future licensee. Details of these are contained in Annex 6.

190. Residual matters are recorded as a minor shortfall if it does not:

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

5 CONCLUSIONS

191. This report presents the findings of my Step 4 external hazards assessment of the Hitachi-GE UK ABWR.

192. To conclude, I am broadly satisfied with the claims, arguments and evidence laid down within the PCSR and supporting documentation for external hazards. I consider that from an external hazards view point, the Hitachi-GE UK ABWR design is suitable for construction in the UK subject to future permissions and permits beings secured.

193. Several assessment findings (annex 5) are identified; these are for future licensee to consider and take forward in their site-specific safety submissions. These matters do not undermine the generic safety submission and need licensee input/decision.

5.1 Key Findings from the Step 4 Assessment

194. I consider that from an external hazards view point, the UK ABWR design is suitable for construction in the UK, at this present time, subject to future permissions and permits beings secured.

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Annex 1

Safety Assessment Principles

SAP No.	SAP Title	Description
EHA.1	Identification and Characterisation	An effective process should be applied to identify and characterise all external and internal hazards that could affect the safety of the facility.
EHA.2	Data sources	For each type of external hazard, either site-specific or, if this is not appropriate, best available relevant data should be used to determine the relationship between event magnitudes and their frequencies.
EHA.3	Design basis events	For each internal or external hazard which cannot be excluded on the basis of either low frequency or insignificant consequence (see Principle EHA.19), a design basis event should be derived.
EHA.4	Frequency of initiating event	For natural external hazards, characterised by frequency of exceedance hazard curves and internal hazards, the design basis event for an internal or external hazard should be derived to have a predicted frequency of exceedance that accords with Fault Analysis Principle FA.5. The thresholds set in Principle FA.5 for design basis events are 1 in 10 000 years for external hazards and 1 in 100 000 years for man-made external hazards and all internal hazards (see also paragraph 629).
EHA.5	Design basis event operating states	Analysis of design basis events should assume the event occurs simultaneously with the facility's most adverse permitted operating state (see paragraph 631 c) and d)).
EHA.6	Analysis	The effects of internal and external hazards that could affect the safety of the facility should be analysed. The analysis should take into account hazard combinations, simultaneous effects, common cause failures, defence in depth and consequential effects.
EHA.7	'Cliff-edge' effects	A small change in design basis fault or event assumptions should not lead to a disproportionate increase in radiological consequences.
EHA.8	Aircraft crash	The total predicted frequency of aircraft crash, including helicopters and other airborne vehicles, on or near any facility housing structures, systems and components should be determined.
EHA.9	Earthquakes	The seismology and geology of the area around the site and the geology and hydrogeology of the site should be evaluated to derive a design basis earthquake (DBE).

SAP No.	SAP Title	Description
EHA.10	Electromagnetic interference	The facility design should include preventative and/or protective measures against the effects of electromagnetic interference.
EHA.11	Weather conditions	Facilities should be shown to withstand weather conditions that meet design basis event criteria. Weather conditions beyond the design basis that have the potential to lead to a severe accident should also be analysed.
EHA.12	Flooding	Facilities should be shown to withstand flooding conditions up to and including the design basis event. Severe accidents involving flooding should also be analysed.
EHA.18	Beyond design basis events	Fault sequences initiated by internal and external hazards beyond the design basis should be analysed applying an appropriate combination of engineering, deterministic and probabilistic assessments.
EHA.19	Screening	Hazards whose associated faults make no significant contribution to overall risks from the facility should be excluded from the fault analysis.
EKP.1	Inherent safety	The underpinning safety aim for any nuclear facility should be an inherently safe design, consistent with the operational purposes of the facility.
EKP.2	Fault tolerance	The sensitivity of the facility to potential faults should be minimised.
EKP.3	Defence in depth	Nuclear facilities should be designed and operated so that defence in depth against potentially significant faults or failures is achieved by the provision of multiple independent barriers to fault progression.
EKP.4	Safety function	The safety function(s) to be delivered within the facility should be identified by a structured analysis.
EKP.5	Safety Measure	Safety measures should be identified to deliver the required safety function(s).
FA.2	Identification of initiating faults	Fault analysis should identify all initiating faults having the potential to lead to any person receiving a significant dose of radiation, or to a significant quantity of radioactive material escaping from its designated place of residence or confinement.
FA.3	Fault sequences	Fault sequences should be developed from the initiating faults and their potential consequences analysed.
FA.4	Fault tolerance	DBA should be carried out to provide a robust demonstration of the fault tolerance of the engineering design and the effectiveness of the safety measures.
FA.5	Initiating faults	The safety case should list all initiating faults that are included within the design basis analysis of the facility.

SAP No.	SAP Title	Description
FA.6	Fault sequences	For each initiating fault within the design basis, the relevant design basis fault sequences should be identified.

Annex 2

Technical Assessment Guide

TAG Ref	TAG Title
NS-TAST-GD-005 Revision 7	Guidance on the Demonstration of ALARP (As Low As Reasonably Practicable)
NS-TAST-GD-013 Revision 4	External Hazards

Annex 3

National and International Standards and Guidance

National and International Standards and Guidance	
NS-R-3	IAEA Safety Standards Series - Site Evaluation for Nuclear Installations
SSG- 21	IAEA Safety Standards Series – Volcanic Hazards in Site Evaluation for Nuclear Installations
SSG-18	IAEA Safety Standards Series – Meteorological and Hydrological Hazards in Site Evaluation for Nuclear Installations
NS-G-1.5	IAEA Safety Standards Series – External Events Excluding Earthquakes in the Design of Nuclear Power Plants
NS-G-1.6	IAEA Safety Standards Series - Seismic Design and Qualification of Nuclear Power Plants
NS-G-3.1	IAEA Safety Standards Series - External Human Induced Events in Site Evaluation for Nuclear Power Plants
SSG-9	IAEA Safety Standards Series - Seismic Hazards in Site Evaluation for Nuclear Installations
NS-G-3.6	IAEA Safety Standards Series - Geotechnical Aspects of Site Evaluation and Foundations for Nuclear Power Plants
TECDOC-1341	IAEA Extreme External Events in the Design and Assessment of Nuclear Power Plants, March 2003
WENRA RHWG	Report on Safety of new NPP (Nuclear Power Plant) designs
EN 1991-1-3	Eurocode 1 Actions on structures, Part 1-3: General actions - Snow loads
EN 1991-1-4	Eurocode 1 Actions on structures, Part 1.4: General actions - Wind actions
EN 1991-1-5	Eurocode 1 Actions on structures, Part 1.5: General actions – Thermal actions
EN 1993-3-1	Eurocode 3 - Design of steel structures, Part 3.1: Towers, masts and chimneys

ASCE 7-10	Minimum Design Loads for Buildings and Other Structures
NRC 1.76	Design-basis Tornado and Tornado Missiles for Nuclear Power Plants
EA	Adapting to Climate Change: Advice for Flood and Coastal Erosion Risk Management Authorities
UKCIP	Interpretation and use of future snow projections from the 11-member Met Office Regional Climate Model ensemble
BSI	Standard for lightning protection, BS EN/IEC 62530
ACI 349-13	Code Requirements for Nuclear Safety Related Concrete Structures
MDEP	Design-Specific Common Position CP-ABWRWG-01

Annex 4

Regulatory Issues / Observations

RI / RO Ref	RI / RO Title	Description	Date Closed	Report Section Reference
RO-ABWR-0055	UK ABWR Generic Site Envelope - Seismic Hazard Definition	Due to the inconsistency between the GDA and site-specific resolution programmes, the GDA seismic hazard definition was decoupled from site-specific work during GDA. Hitachi-GE developed a seismic design spectra based on generic UK data for the purposes of GDA.	26 August 2015	4.2.2.9
RO-ABWR-0067	UK ABWR Generic Site Envelope – External Flooding and Beyond Design Basis Events	My assessment of Hitachi-GE's submissions identified shortfalls in respect of the treatment of beyond design basis assessment of external hazards generally, and external flooding specifically. Hitachi-GE provided additional analysis and documentation with respect to beyond design basis hazards for the UK ABWR generic design.	5 June 2017	4.2.4

Annex 5

Assessment Findings

Assessment Finding Number	Assessment Finding	Report Section Reference
AF-ABWR-EH-01	As a result of the assumptions made in the Generic Site Envelope for GDA, a future licensee shall perform a site-specific assessment to determine the design basis tornado wind speed. Depending on the results of the assessment, the implications of the maximum wind speed of a T2 tornado should be compared with the design withstand to demonstrate that the impact is acceptable with adequate margins.	4.2.2.2
AF-ABWR-EH-02	Due to the requirement for detailed design information and due to developments in methods of assessment, a future licensee shall consider sources of naturally-occurring Electro-Magnetic Interference from extreme space weather events including geomagnetic storms, solar radiation storms, and radio blackouts. This shall include an assessment of hazard magnitudes, frequencies, and potential effects, along with reasonably practicable resilience enhancements to protect against these hazards to reduce risks ALARP.	4.2.2.6
AF-ABWR-EH-03	As a result of the assumptions made in GDA, a future licensee shall review the combinations of hazards at the site-specific stage ensure that all reasonably foreseeable combinations of hazards for a specific site have been included in the analysis.	4.2.3
AF-ABWR-EH-04	As a result of the assumptions made in GDA, a future licensee shall consider and implement adequate water sealing and/or elevation of the Heat Exchanger Building and transformer, Reactor Building, Control Building, Electrical Diesel Generator Buildings, and Backup Building. The determination of requirements shall be based on site-specific evaluation of external flooding beyond the design basis in accordance with the principles of ALARP.	4.2.4.1
AF-ABWR-EH-05	As a result of assumptions made concerning Beyond Design Basis hazards in GDA, a future licensee shall consider whether or not the site-specific seismic analysis demonstrates that the generic site envelope's seismic hazard definitions are bounding. If the generic site envelope's seismic hazard definitions are not bounding, a future licensee shall assess the vulnerabilities of the UK ABWR to beyond design basis hazards assumed in the generic design to be bounded by generic site envelope seismic hazard definitions.	4.2.4.2

Annex 6

Minor Shortfalls

Minor Shortfall Number	Minor Shortfall Finding	Report Section Reference
MS-ABWR-EH01	Hitachi-GE does not consider barrier ice formation to be credible for the UK Generic site. I agree with this - however the argument would be better reinforced by identifying the depth of the intake heads to demonstrate a margin and I consider this a minor shortfall.	4.2.2.3
MS-ABWR-EH02	The support document on EMI for the Generic Site Envelope continues to make some limited reference to the previous 200kA GSE value (now replaced by 300kA). This could be interpreted as suggesting that it is reasonable for the electrical protection system to be designed in accordance with lightning protection level 1 (ie 200kA) which is not the case. This statement may cause confusion and I consider this to represent a minor shortfall.	4.2.2.6