Office for Nuclear Regulation

New Reactors Division

Step 4 Assessment of Decommissioning for the UK Advanced Boiling Water Reactor

Assessment Report: ONR-NR-AR-17-034-UK ABWR
Revision 0
December 2017

Published 12/2017

EXECUTIVE SUMMARY

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

GDA is a four step process. This report summarises ONR's step 4 GDA of Hitachi-GE's UK ABWR design in the topic area of decommissioning and was completed by ONR's Nuclear Liabilities Regulation Specialism (NLR). The step 4 assessment consists of a review of the safety, security and environmental aspects of the UK ABWR in greater detail than in the preceding steps. In step 4 ONR examined the evidence supporting the claims and arguments made in the safety documentation, building on the assessments completed in steps 2 and 3. This includes ONR's judgements on the adequacy of the information contained within Hitachi-GE's Pre-Construction Safety Report (PCSR) and its supporting documentation.

GDA concerns the early stages of design. As decommissioning of the UK ABWR is not planned to begin for at least 65 years after the completion of GDA, ONR's key priority for this assessment was to ensure the UK ABWR design will be consistent with the internationally recognised principle of 'design for decommissioning', such that the risks of future decommissioning will be reduced So Far As Is Reasonably Practicable (SFAIRP).

Due to the long timescales associated with decommissioning the UK ABWR and the immature status of some parts of the design within GDA, Hitachi-GE's case had to accommodate unavoidable uncertainties. ONR therefore sought assurance that Hitachi-GE had adopted a precautionary approach to uncertainty, such that the viability of the intended decommissioning strategy and techniques does not depend on potentially optimistic assumptions on how the UK ABWR will perform in practice.

A future licensee will have significant time to consider the management arrangements that will apply during the delivery of decommissioning, such as the adequacy of decommissioning skills, resource levels, change control and the engagement of specialist contractors. The global nuclear industry already contains considerable experience of these aspects of decommissioning and ONR has a high level of confidence that it will be feasible for a future licensee to put adequate management arrangements in place to deliver decommissioning at the appropriate time.

The UK Government legislated in The Energy Act 2008 to ensure operators of all new nuclear power stations will have secure finances in place to meet the full costs of decommissioning and waste management. The Act requires operators to put in place a Funded Decommissioning Programme (FDP), approved by the Secretary of State, before construction of a new nuclear power station begins and to comply with the FDP thereafter. The FDP must set out the plans for decommissioning, waste management and waste disposal, estimate the associated costs and describe how the operator will ensure it has sufficient assets/funds available to meet those costs. To support operators in developing their FDPs, the Government developed a Base Case which outlines key strategic assumptions that are expected to define parts of the lifecycle. Several of the Base Case assumptions are relevant to the site decommissioning strategy and plan. Through the course of this assessment ONR has therefore checked that Hitachi-GE's proposals are compatible with the government Base Case for new nuclear power stations, or any deviations from the Base Case are appropriately justified. This includes an expectation that decommissioning should be achievable using currently available technology. The decommissioning strategy and plan also needed to accommodate an extended period of safe on-site storage for Higher Activity Wastes (HAW) and spent fuel, until such time as the UK's planned Geological Disposal Facility (GDF) becomes available to enable their direct disposal.

ONR recognises that emergence of new information, progress in decommissioning techniques and changes in relevant standards are likely to occur prior to the UK ABWR reaching the end of its operational life. During that time the UK ABWR decommissioning strategy, plan and intended techniques will need to be regularly reviewed and updated by a future licensee, as

part of normal regulatory business in accordance with ONR's expectations for Site Licence Conditions 15 and 35 of the Nuclear Installations Act 1965 (NIA65).

ONR's key assessment conclusions are:

- Hitachi-GE has developed a decommissioning strategy and plan for the UK ABWR, based on prompt dismantling after the reactor's 60-year operating life, which aligns with UK law, UK Government policy and is consistent with regulatory expectations.
- Hitachi-GE has provided adequate evidence that it is technically feasible for the UK ABWR design to be safely decommissioned using current technology.
- Hitachi-GE's intended end-point for decommissioning of the UK ABWR is for the site to be delicensed and Hitachi-GE has taken steps to ensure that the design is compatible with achievement of that objective. This position is consistent with UK law and regulatory expectations.
- Hitachi-GE has provided adequate evidence that all the radioactive wastes expected to be generated during decommissioning of the UK ABWR can be appropriately managed and should be disposable at current or planned facilities within the UK.
- Hitachi-GE has challenged its reference design and operating philosophy for the UK ABWR to identify potential improvements that can reduce the risks of future decommissioning SFAIRP.

ONR's judgement is based on the following factors:

- Compatibility of Hitachi-GE's decommissioning strategy and plan with UK Government policy, including the strategic-level assumptions in UK Government's Base Case for the decommissioning of new nuclear power stations associated with The Energy Act 2008.
- Hitachi-GE's identification of a comprehensive set of decommissioning techniques, with due consideration of current relevant good practice.
- Hitachi-GE's identification and justification of key assumptions that underpin the proposed decommissioning strategy, plan and techniques.
- Hitachi-GE's recognition within the UK ABWR safety case of the standards currently applied to delicensing of UK nuclear sites and the need for the design to be compatible with achievement of the 'no danger' criterion.
- Hitachi-GE's accommodation within its decommissioning plan of a period of safe long-term on-site storage for spent fuels and HAW, aligned with the anticipated timescales for the UK government's development of a GDF.
- Hitachi-GE's engagement with Nuclear Decommissioning Authority (NDA) Radioactive Waste Management Limited (RWM Ltd) and associated assessment of the disposability of the HAW and spent fuels expected to arise from the UK ABWR.
- Hitachi-GE's application of a Hazard and Operability study (HAZOP) to challenge the UK ABWR reference design and identify reasonably practicable improvements to reduce the challenges and risks of decommissioning SFAIRP.

The following matters remain, which are for a licensee to consider and take forward in its site-specific submissions. These matters do not undermine ONR's confidence in the generic safety case, but require licensee input/decisions to be made in relation to a specific site:

- Hitachi-GE's generic safety case for decommissioning was based on a strategy of prompt dismantling, with some reliance on Systems, Structures and Components (SSCs) that will be in-situ during station operations to support delivery of decommissioning activities. Whilst this provided sufficient evidence for the purpose of leaving GDA, the generic case

did not take account of reasonably foreseeable events (such as a delay to decommissioning timescales) and did not comprehensively capture all the functional and service life requirements for all relevant SSCs to support Post Operational Clean Out (POCO) and decommissioning. Therefore the licensee shall ensure that when considering decommissioning:

- The UK ABWR civil structures are designed such that all relevant safety functions can be delivered for as long as necessary, should the timescales of decommissioning need to be extended beyond the plan provided in the generic safety case.
- Adequate consideration is given to the requirement for auxiliary systems that support station operations to contribute to POCO and decommissioning, noting the potential for more onerous demands to be placed on some SSCs during POCO and decommissioning than in normal operations.

- Hitachi-GE's generic safety case claimed that the Human Factors considerations for maintenance of replaceable items during the UK ABWR's operations are representative and bounding of the intended decommissioning activities. As substantiation of this claim is dependent on site specific information, the licensee shall at appropriate times during detailed design, construction and operation of the UK ABWR:
  - Review the decommissioning plan and maintenance schedule, to confirm whether the Human Factors considerations for maintenance of replaceable items during station operations are, so far as is reasonably practicable (SFAIRP), representative and bounding of the intended decommissioning activities.
  - Substantiate that appropriate working conditions can be provided to operators SFAIRP during decommissioning, taking into account provision of sufficient space, supporting services and the intended decommissioning methods.
- Hitachi-GE's generic safety case identified the potential for advanced modular construction techniques to be used in building the UK ABWR and the possibility that such techniques may have negative impacts for decommissioning.

  Should the licensee decide to use advanced modular techniques in construction of the UK ABWR, it shall demonstrate that it has considered all reasonably practicable measures to minimise any negative impacts from these techniques for decommissioning, including a consideration of:
  - Unobstructed egress routes for equipment and items to be removed during decommissioning
  - Sufficient space for operators to undertake decommissioning tasks
  - Engineering of walls to enable them to be safely removed to assist decommissioning
- Knowledge management is of key importance to decommissioning, given the need to maintain an accurate understanding of the 'as built' plant over long durations.

  Whilst Hitachi-GE's generic safety case provided sufficient recognition of knowledge management, the eventual method will be highly reliant on site-specific conditions and the licensee's operational choices.

  Therefore the licensee shall develop, so far as is reasonably practicable, robust arrangements to capture relevant knowledge for the delivery of decommissioning throughout all the preceding stages of the plant's life. These arrangements should ensure the licensee maintains an accurate understanding of the 'as built' plant and radioactive wastes over the required timescales, including any significant design changes, process modifications and any departures from the expected plant conditions.

To conclude, I am broadly satisfied with the claims, arguments and evidence laid down within the UK ABWR generic PCSR and supporting documentation for the Decommissioning topic. Therefore, from the perspective of Decommissioning I have no objection to Hitachi-GE's UK ABWR design being awarded a Design Acceptance Confirmation (DAC).

LIST OF ABBREVIATIONS

ABWR	Advanced Boiling Water Reactor
ALARP	As Low As Reasonably Practicable
BAT	Best Available Techniques
BWR	Boling Water Reactor
CDM	Construction (Design and Management) Regulations 2015
DAC	Design Acceptance Confirmation
DSP	Dryer Separator Pool
ENSREG	European Nuclear Safety Regulators Group
ERIC-PD	Eliminate, Reduce, Isolate, Control, Personal Protective Equipment and Discipline
EUST	End User Source Term
FDP	Funded Decommissioning Programme
FRF	Fuel Repackaging Facility
GDA	Generic Design Assessment
GDF	Geological Disposal Facility
GEP	Generic Environmental Permit
HAW	Higher Activity Waste
HAZOP	Hazard and Operability
HFE	Human Factors Engineering
HLW	High Level Waste
HVAC	Heating Ventilation and Air Conditioning
IAEA	The International Atomic Energy Agency
ILW	Intermediate Level Waste
IWS	Integrated Waste Strategy
LLW	Low Level Waste
MDEP	Multi-national Design Evaluation Programme
MSQA	Management for Safety and Quality Assurance
NDA	Nuclear Decommissioning Authority
NIA65	Nuclear Installations Act 1965
NLFAB	Nuclear Liabilities Funding Assurance Board
NLR	Nuclear Liabilities Regulation
NRW	Natural Resources Wales
OECD-NEA	Organisation for Economic Co-operation and Development - Nuclear Energy Agency
ONR	Office for Nuclear Regulation
OPEX	Operational Experience
PCSR	Pre-Construction Safety Report
POCO	Post Operational Clean Out
PSA	Probabilistic Safety Assessment

PWR	Pressurised Water Reactor
RBC	Reactor Building Crane
RGP	Relevant Good Practice
RI	Regulatory Issue
RO	Regulatory Observation
RP	Requesting Party
RPV	Reactor Pressure Vessel
RQ	Regulatory Query
R2P2	Reducing Risks, Protecting People (a HSE publication)
RWM Ltd	Radioactive Waste Management Limited
RWMA	Radioactive Waste Management Arrangements
SAPs	Safety Assessment Principles
SC	Safety Claim
SFAIRP	So Far As Is Reasonably Practicable
SFIS	Spent Fuel Interim Storage
SFP	Spent Fuel Pool
SoDA	Statement of Design Acceptability
SSC	System, Structure (and) Component
TAG	Technical Assessment Guide
TRL	Technology Readiness Level
TSC	Technical Support Contractor
US NRC	United States (of America) Nuclear Regulatory Commission
UK ABWR	United Kingdom Advanced Boiling Water Reactor
WENRA	Western European Nuclear Regulators' Association

TABLE OF CONTENTS

Tables

Figures

Annexes

1 INTRODUCTION

1.1 Background to GDA

1. Information on the Generic Design Assessment (GDA) process is provided in a series of documents published to a dedicated area of ONR's website (http://www.onr.org.uk/new-reactors/index.htm). GDA consists of a rigorous regulatory assessment of the design of a proposed new nuclear power station, which if completed successfully will result in the Requesting Party being awarded a Design Acceptance Confirmation (DAC) from ONR and a Statement of Design Acceptability (SoDA) from the Environment Agency and Natural Resources Wales (NRW).

2. Hitachi-GE is the Requesting Party for the UK ABWR design which commenced GDA in 2013 and completed the process in 2017. Full technical details of the UK ABWR are available via http://www.hitachi-hgne-UK ABWR.co.uk/

3. GDA consists of four steps. A report summarising the outputs from Step 3 for the UK ABWR was published on ONR's website (Ref.1).

4. Step 4 consists of an in-depth assessment of the safety, security and environmental evidence provided by a Requesting Party. Through the review of information provided to ONR, the Step 4 process for the UK ABWR aimed to confirm that Hitachi-GE:

   - Has properly justified its higher-level claims and arguments.
   - Has adequately progressed the resolution of any issues identified during Steps 2 and 3.
   - Has provided sufficient detailed analysis to allow ONR to come to a judgment of whether a DAC can be issued.

5. During Step 4 ONR has undertaken a detailed assessment, on a sampling basis, of Hitachi-GE's safety and security case evidence. Items that might form part of such an assessment are outlined in ONR's GDA Guidance to Requesting Parties (Ref.2). For the purpose of this assessment, the following items had particular relevance:

   - Judging against the Safety Assessment Principles (SAPs) (Ref.3) and relevant Technical Assessment Guides (TAGs) whether the proposed design will reduce risks so far as is reasonably practicable (SFAIRP).
   - Establishing whether the system performance, safety classification, and reliability requirements are adequately substantiated.
   - Arrangements to ensure that safety claims and assumptions are realised in the final as-built design.
   - Clear and traceable links between underpinning data, Topic Reports and the generic Pre-Construction Safety Report (PCSR).
   - An objective demonstration that the design reflects UK law, Government policies, standards and other regulatory expectations.
   - Arrangements to ensure any significant impacts from design changes and process modifications are properly recognised and taken into account.
   - An assessment of the disposability of radioactive wastes and spent fuel arising from operation and decommissioning of the UK ABWR.

6. All the regulatory issues (RIs) and regulatory observations (ROs) issued to Hitachi-GE during GDA have been published on ONR's website, together with the corresponding Hitachi-GE resolution plans and confirmation of RI and RO closure.

1.2 Scope of this Assessment

7. At the start of Step 4, the scope of ONR's GDA for decommissioning was outlined in an assessment plan (Ref.4).

8. Although decommissioning is the last stage of the overall lifecycle of a nuclear power station, the UK regulators expect that the need to ultimately decommission the plant should be taken into account during the earliest stages of design. ONR's key objective in regulating decommissioning is to secure a progressive reduction in hazard when a nuclear facility reaches the end of it operational life, in a way that optimises the protection of individuals, society and the environment.

9. In order to deliver a targeted and proportionate assessment, ONR's approach was tailored to match the status of the UK ABWR design within GDA. ONR's identified priorities were:

   - For Hitachi-GE's decommissioning strategy, plan and proposed techniques to be compliant with relevant UK law, compatible with UK Government policy and aligned with regulatory expectations.
   - To ensure the UK ABWR complies with the internationally recognised principle of 'Design for Decommissioning' (Ref.5), wherein the design should take account of the need to achieve future decommissioning and ensure the associated risks are reduced SFAIRP.
   - Assurance that Hitachi-GE's proposals for decommissioning were based on a precautionary approach to uncertainty, such that the technical viability of the intended decommissioning strategy and techniques did not depend on optimistic assumptions on how the UK ABWR will perform in practice.
   - To ensure the needs of decommissioning were recognised in all relevant areas of the generic safety case, including the sections dedicated to engineering, conventional safety and radiological protection.

1.3 Method

10. This assessment complies with ONR internal guidance on the mechanics of assessment (Ref.6).

11. Decommissioning involves many technical disciplines with interests in particular aspects of safety and environmental protection, such that this assessment could not be carried out in isolation and had to be integrated with ONR's consideration of other GDA topics. Further information on the key multi-disciplinary interfaces is provided in Section 2.3.

2 ASSESSMENT STRATEGY

2.1 Standards and Criteria

12. The standards and criteria adopted within this assessment are principally ONR's SAPs, relevant Technical Assessment Guides (TAGs), other regulatory guidance, applicable national and international standards and relevant good practice informed from existing practices adopted on UK nuclear licensed sites.

2.1.1 Safety Assessment Principles

13. The key SAPs that were applied to this assessment are listed in Annex 1.

2.1.2 Technical Assessment Guides

14. The key TAGs that were applied to this assessment are listed in Annex 2.

2.1.3 National and International Standards and Guidance

15. The further national and international standards and guidance that were applied to this assessment are included in Annex 3.

2.2 Use of Technical Support Contractors (TSCs)

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

17. A single TSC from Quintessa Ltd was engaged during Step 4 to support ONR's assessment of decommissioning for the UK ABWR. Table 1 sets out the broad areas in which this technical support was used.

Table 1

Use of Technical Support Contractor
Technical reviews of Hitachi-GE's submissions against the SAPs, TAGs, legislation and other relevant regulatory expectations
Reporting of any shortfalls identified during reviews of Hitachi-GE's submissions, including a commentary on their significance
Provision of independent technical advice
Support to ONR in Level 4 technical discussions with the Requesting Party
Drafting of requests for additional information and provision of advice to ONR on the adequacy of Hitachi-GE's responses
Drafting of reports

18. While the TSC undertook detailed technical reviews, this was done under ONR's direction and supervision and the regulatory judgement on the adequacy of the decommissioning case for the UK ABWR has been made exclusively by ONR.

2.3 Integration with other assessment topics

19. In GDA the Requesting Party is expected to submit a safety case, within which all aspects of the design relevant to decommissioning should be addressed. The safety case for each stage in the life of a nuclear power station should demonstrate the safety of that stage before it commences and should be forward looking to subsequent stages. Any constraints imposed on subsequent stages should be identified. For facilities under design or construction, the safety case should contain sufficient detail to give confidence that the safety intent will be achieved in the subsequent stages of commissioning, operation and decommissioning.

20. Decommissioning involves remediation of the totality of the hazards on a site and removal of the systems that were used to protect against those hazards when the site was operational. Therefore the related claims, arguments, evidence and assumptions reach across several technical areas. Consequently this assessment had to be integrated with the consideration of several other GDA topics – the following list explains the key interfaces.

- **Management of Radioactive Wastes** involves the Requesting Party's strategies, plans and design of systems to deliver adequate levels of safety whilst managing the anticipated gaseous, liquid and solid radioactive wastes from the power station's operational phase. In addition to meeting the requirements of UK law, the generic safety case was expected to be consistent with UK waste policies, the predicted national waste management infrastructure and good practices in waste management such that the following fundamental regulatory expectations will be satisfied:
  - The waste hierarchy should be applied.
  - Radioactive waste should be managed safely throughout its life cycle in a manner that is consistent with modern standards.
  - The anticipated disposal routes should be taken into account.
  - Where disposal is not available in the short term, radioactive waste should be put into a passively safe state for interim storage, pending future disposal or other long-term solution.

  ONR's assessment of Hitachi-GE's generic safety case for Management of Radioactive Wastes is reported in Ref.7.
- **Spent Fuel Interim Storage** focusses on the robustness of Hitachi-GE's generic safety case for on-site dry cask storage of spent fuel, together with key parts of the preceding processes whose efficacy will underpin the safety of the dry storage period. This assessment did not give detailed consideration to Hitachi-GE's proposals for the wet storage period that spent fuel will undergo in the Spent Fuel Pool immediately after leaving the reactor, as specific aspects of those arrangements were assessed by other ONR specialisms throughout the GDA.

  ONR also considered the compatibility of Hitachi-GE's approach to managing spent fuel with relevant parts of UK government policy, including key strategic-level assumptions in the government's Base Case for the expected lifecycle of new nuclear power stations associated with The Energy Act 2008. For example, the Base Case includes an expectation that operators of new nuclear power stations should plan on the basis that their spent fuel will not be reprocessed.

  ONR's assessment of Hitachi-GE's generic safety case for Spent Fuel Interim Storage is reported in Ref.8.

- **Reactor Chemistry** concerns the control of coolant chemistry and has implications for the plant functionality in relation to core reactivity, pressure boundary integrity, fuel and core component performance, materials selection, cooling of spent fuel in

the Spent Fuel Pool, levels of contamination on primary circuit surfaces and minimisation of radioactive wastes.

Definition and optimisation of the radioactive source term for decommissioning, i.e. the nature and amount of radioactivity expected to be present in the UK ABWR systems at the end of the station's operational life, was a fundamental input to Hitachi-GE's demonstration that its proposals for decommissioning were technically viable.

ONR's assessment of the Reactor Chemistry elements of Hitachi-GE's generic safety case is reported in Ref.9.

- **Civil Engineering** deals with the design, construction and maintenance of structures that will provide shielding, retain nuclear matter, provide physical support to other safety-related systems and protect safety-related plant from external hazards.

  During GDA, ONR sought assurance that Hitachi-GE had considered the incorporation of civil engineering features to facilitate future decommissioning, such as the provision of egress routes for the large heavy contaminated items that will need to be removed during decommissioning and surface finishes that can be easily decontaminated. Wherever civil structures will contribute to safety during decommissioning, ONR sought evidence to demonstrate that safety can be adequately maintained for the time periods required.

  ONR's assessment of the Civil Engineering elements of Hitachi-GE's generic safety case is reported in Ref.10.

- **Human Factors** considerations during decommissioning can involve unique risks to workers.

  In respect of the operational phase for nuclear facilities, safety cases are expected to substantiate the way safety measures are distributed between humans and technology, such that the dependence on human actions to maintain a safe state is minimised SFAIRP. However the circumstances of decommissioning can give rise to specialist demands, as the site's radiological hazards and the engineered systems designed to provide protection during the operational phase are progressively removed.

  ONR expects the highest levels of safety that can reasonably be achieved should be provided at all times. It is therefore important for the design to ensure the potential for human error to give rise to significant consequences, in the particular circumstances of decommissioning, will be reduced SFAIRP.

  ONR has considered the adequacy of Hitachi-GE's overall approach to Human Factors in Ref.11. Targeted aspects of Human Factors that are specific to the decommissioning topic have been assessed within this report.

- **Radiological Protection** measures to restrict the extent of contamination throughout the plant during its operational phase are important in reducing the hazard associated with decommissioning.

  When decommissioning commences, tasks such as breaking into the cells, vessels and pipework that were used to contain and transfer radioactive material will require particular attention. In such circumstances ONR's SAPs highlight the importance of radiation sources being eliminated or controlled before placing a reliance on the actions of individuals to maintain safety. ONR therefore sought assurance that the UK ABWR design provides for an engineered and remote means of decommissioning so far as reasonably practicable, before it will become necessary to resort to systems of work, administrative measures or personal protective equipment.

ONR also examined Hitachi-GE's strategy for decontamination in the decommissioning context, to ensure that due consideration was given to all relevant factors, including potential benefits (e.g. reducing the categorisation of waste items to simplify their disposal) and detriments (e.g. elevated worker doses from manual decontamination and generation of secondary wastes).

ONR's assessment of the Radiological Protection elements of Hitachi-GE's generic safety case is reported in Ref.12.

- **Conventional Health and Safety** is a significant consideration during decommissioning due to the risks from the typical processes such as hot cutting, work at height, chemical decontamination, work in confined spaces, ad-hoc lifting operations, demolition of civil structures and size reduction of large items.

  ONR's expectation is for Hitachi-GE to implement design measures to reduce the conventional health and safety risks associated with decommissioning SFAIRP, in accordance with the requirements of the Construction (Design and Management) Regulations 2015 and other sources of regulatory expectations.

  ONR's assessment of the Conventional Health and Safety elements of Hitachi-GE's generic safety case is reported in Ref.13.

- **Fault Studies** involves a consideration of fault sequences and postulated accident conditions, leading to the assignment of categorisations to the systems, structures and components (SSCs) that provide relevant lines of protection and/or mitigation.

  As decommissioning involves a scope of work activities and design basis events that differs from the operational phase, it may place different demands on some of the UK ABWR engineering and protection systems. ONR has therefore sought assurance that Hitachi-GE's approach to categorisation and classification of SSCs has taken account of the requirements of decommissioning.

  ONR's assessment of Hitachi-GE's generic safety case in the topic area of Fault Studies is reported in Ref.14.

- **Mechanical Engineering** systems make major contributions to decommissioning in respect of dismantling, size reduction, lifting, transfer and packaging of redundant plant. Some typical decommissioning tasks, such as scabbling of concrete and hot cutting of radioactive metals, also give rise to particular demands for nuclear ventilation.

  ONR has sought evidence to confirm that the need for the mechanical systems provided during earlier phases of the UK ABWR lifecycle (such as the Reactor Building Crane) to contribute to ultimate decommissioning has been adequately taken into account in the initial design. In accordance with the principle of 'design for decommissioning', the functionality and service life of such systems should be compatible with the intended decommissioning plan and techniques, reducing the need for complicated modifications to be made at the end of the site's operational life.

  ONR's assessment of the Mechanical Engineering elements of Hitachi-GE's generic safety case is reported in Ref.15.

- **Management of Safety and Quality Assurance** (MSQA) arrangements should capture all knowledge and data relevant to decommissioning, including details of the 'as-built' plant and any modifications that have a significant implication for future decommissioning.

  ONR's expectation is for such arrangements to allow for retention of all information relevant to decommissioning, starting from the initial stages of design.

  ONR's assessment of Hitachi-GE's generic safety case in the topic area of MSQA is reported in Ref.16.

- **Environmental Protection** is a particularly important consideration during decommissioning, given the relatively large volumes of radioactive and conventional wastes that will be generated when compared to the operational phase.

  Consideration of these aspects has required close liaison between ONR and the environmental regulators throughout GDA, due to common interests and the need to regulate in a coordinated manner. Joint working between the regulators has been delivered throughout the GDA process in accordance with established memorandums of understanding, to ensure an efficient and integrated oversight of Hitachi-GE's proposals in terms of both nuclear safety and environmental protection.

2.4 Sampling strategy

21. 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.

22. This assessment has been based on a targeted sample of the evidence provided by Hitachi-GE, against the priorities set out in the Step 4 assessment plan and consistent with ONR's Enforcement Policy Statement (Ref.17), with the highest level of scrutiny focussed on those parts of the decommissioning case that concerned the greatest hazards and risks.

23. ONR applied particular scrutiny to the areas of Hitachi-GE's safety case which provided claims, arguments and evidence relevant to ONR's priorities for the decommissioning topic within GDA, i.e.:

- Compliance with relevant UK law, compatibility with UK government policy and alignment with regulatory expectations.
- Achievement of 'design for decommissioning'.
- A demonstration that Hitachi-GE's proposals are based on a precautionary approach to uncertainty.
- Ensuring the needs of decommissioning were recognised in all relevant areas of the generic safety case.

24. Due to the long timescales associated with decommissioning of the UK ABWR and the status of the design within GDA, Hitachi-GE's case had to accommodate some unavoidable uncertainties. In such cases ONR expects that a precautionary approach should be applied, which errs on the side of safety. A particular priority in this regard was for Hitachi-GE's case to provide assurance that the technical viability of its decommissioning strategy, plan and techniques was not dependent on potentially optimistic assumptions on how the UK ABWR will perform in practice. ONR therefore targeted for greater scrutiny those parts of Hitachi-GE's case that may be vulnerable to 'cliff-edge' effects in the event that underpinning assumptions prove to be incorrect – this included Hitachi-GE's plans for management of decommissioning wastes whose categorisation is subject of uncertainty.

2.5 Out of Scope Items

25. Table 2 sets out the most significant items that were deemed out-of- scope for this assessment.

Table 2

Items Deemed Out-of-Scope of ONR's Decommissioning Assessment for the UK ABWR GDA	
Financial Arrangements for Decommissioning	The UK Government legislated in The Energy Act 2008 to ensure operators of new nuclear power stations will have secure finances in place to meet the full costs of decommissioning and waste management. The Act requires future operators to put in place a Funded Decommissioning Programme (FDP), approved by the Secretary of State, before construction of a new nuclear power station begins and to comply with the FDP thereafter. Impartial scrutiny of the financial arrangements that underpin FDPs and associated advice to the Secretary of State is provided by the Nuclear Liabilities Financing Assurance Board (NLFAB).
Land Use Planning	Land Use Planning is regulated by the appropriate planning authority, who will judge in due course the appropriateness of any future proposals to put a nuclear site to an alternative use after its decommissioning is completed. Hitachi-GE's targeted end point for decommissioning the UK ABWR is delicensing of the site, which will end the licensee's period of responsibility under NIA65.
Environmental Protection	The UK's environmental regulators are responsible for enforcement of the Environmental Permitting Regulations 2016 in relation to disposal of radioactive wastes from nuclear sites. These aspects of the UK ABWR have been duly considered by the Environment Agency within GDA and were therefore out-of-scope of ONR's assessment.

26. A future licensee will have significant time to consider the management arrangements that will apply when decommissioning is carried out, such as the adequacy of decommissioning skills, resource levels, change control and the engagement of specialist contractors. The global nuclear industry already contains considerable experience of these aspects of decommissioning and ONR has a high level of confidence that it will be feasible for a future licensee to put in place adequate management arrangements at the appropriate time. Management arrangements for the practical delivery of decommissioning were therefore not a priority for this assessment.

27. The Energy Act 2008 requires operators of new nuclear power stations in the UK to develop an FDP, which needs to be approved by the Secretary of State before nuclear-related construction on site can begin. The FDP must set out the plans for decommissioning, waste management and waste disposal, estimate the associated costs and describe how the operator will ensure it has sufficient assets/funds available to meet those costs (Ref.18).

28. The Nuclear Liabilities Financing Assurance Board (NLFAB), an independent advisory non-departmental public body, will scrutinise the financial provisioning systems underpinning the FDP and provide its advice to the Secretary of State on the FDP's acceptability.

29. To ensure the Secretary of State and the NLFAB have a consistent benchmark against which to assess the cost estimates produced by operators, the government developed a Base Case which lays out key strategic assumptions that define parts of the lifecycle plan for management of wastes and decommissioning. Some of these assumptions are relevant to the site decommissioning strategy and plan, such as:

- The start of decommissioning is defined as the point when the station is shut down with no intention of further use for the purpose of generating electricity.

- Decommissioning of the power station will be undertaken promptly after it shuts down, with no care and maintenance period after the station has been shut down.
- The operator will ensure all facilities on site are decommissioned in accordance with a structured plan, which is acceptable to the regulators and which should reduce the hazard presented by the site in a systematic manner.
- Dose limits for workers and the public will remain unchanged from those in current use in the UK (set out in the Ionising Radiation Regulations 1999).
- Spent fuel will be kept in interim storage on the site until the point at which it is disposed of in a UK GDF and encapsulation of the spent fuel will also be carried out on the site.
- Intermediate Level Wastes (ILW) from operations and decommissioning are assumed to be stored in safe and secure facilities on the site, pending disposal in the GDF. Operators are therefore expected to set out provision for safe and secure interim storage facilities that are capable of being maintained or replaced until the ILW contained within them can be disposed of.
- On site storage facilities must ensure that the spent fuel and stored HAW will be able to meet the GDF operator's conditions for acceptance at the date scheduled for its disposal.
- Decommissioning will be undertaken using equipment and techniques available at the time the FDP is submitted. While it is recognised that technical advances may well have a significant impact on the way in which new nuclear power stations are eventually decommissioned, operators must be able to demonstrate that they have a workable plan for decommissioning and waste management using current technology before construction of the station begins.
- Decommissioning is defined to end when all station buildings and facilities have been removed and the site has been returned to an end state which has been agreed with the regulators and the planning authority.

30. To ensure that Hitachi-GE's proposals for decommissioning the UK ABWR were aligned with government policy, ONR checked that the generic safety case was either compatible with the above key assumptions or any deviations from the Base Case were adequately justified.

31. However GDA does not include an assessment of the arrangements for financial provisioning that a future operator of a UK ABWR will need to put in place to ensure sufficient monies or assets are available to cover the costs of decommissioning.

3 REQUESTING PARTY'S SAFETY CASE

32. Throughout its generic safety case for the UK ABWR, Hitachi-GE followed the Claims-Arguments-Evidence structure that the regulatory assessment steps for GDA are based on, as described in the Guidance to Requesting Parties (Ref.2).

33. Hitachi-GE's claims were presented in its top-level submission, i.e. Chapter 31 of the generic PCSR, which summarised the totality of the decommissioning safety case. Arguments and evidence against each claim were then presented in seven supporting Topic Reports. Each of the seven Topic Reports also relied on further underpinning references.

34. In completing its assessment ONR considered the consistency of key inter-linkages between Hitachi-GE's submissions on decommissioning and other parts of the safety case that were concerned with engineering of relevant SSCs.

35. Hitachi-GE's key submissions for decommissioning are listed in Table 3.

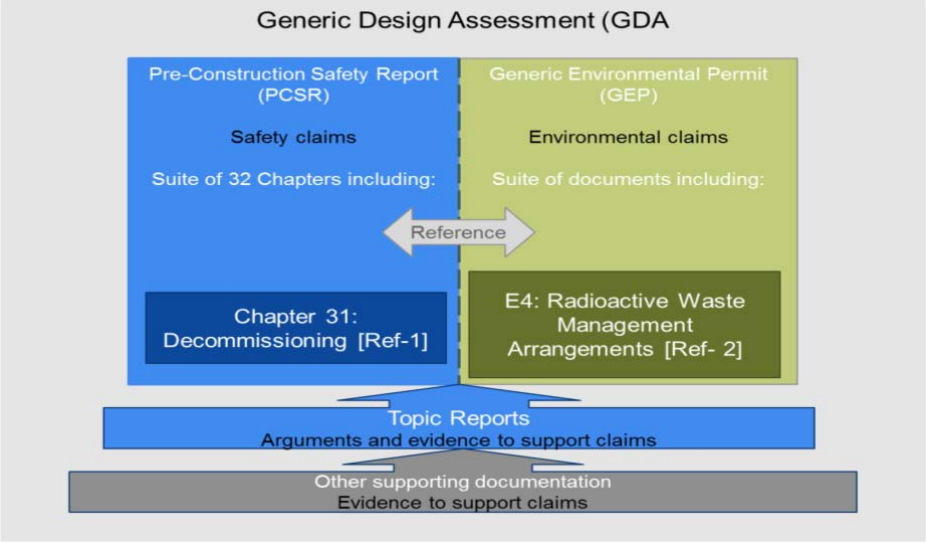
Table 3

Principal Hitachi-GE Safety Case Documentation for Decommissioning in Step 4	
Document ID	**Title**
GA91-9101-0101-31000, DCE-GD-0007, Revision C, 31st August 2017 (Ref.19)	Generic PCSR Chapter 31: Decommissioning
GA91-9201-0001-00176, DCE-GD-0066, Revision 3, 27th July 2017 (Ref.20)	Topic Report: Decommissioning Plan
GA91-9201-0001-00172, DCE-GD-0065, Revision 3, 27th June 2017 (Ref.21)	Topic Report: Design for Decommissioning
GA91-9201-0001-00174, DCE-GD-0067, Revision 2, 28th June 2017 (Ref.22)	Topic Report: Decommissioning Techniques
GA91-9201-0001-00175, DCE-GD-0064, Revision 3, 28th July 2017 (Ref.23)	Topic Report: Decommissioning Strategy
GA91-9201-0001-00178, DCE-GD-0068, Revision 1, 30th March 2017 (Ref.24)	Topic Report: Impact of Construction Techniques on Decommissioning
GA91-9201-0001-00173, DCE-GD-0069, Revision 6, 28th July 2017 (Ref.25)	Topic Report: Decommissioning Waste Management
GA91-9201-0001-00177, DCE-GD-0070, Revision 2, 27th June 2017 (Ref.26)	Topic Report: Decommissioning Safety Assessment
GA91-9201-0003-01346, DCE-GD-0081, Revision 1, 30th March 2017 (Ref.27)	HAZOP Report - Activities within the Decommissioning Phase on UK ABWR
GA91-9201-0003-01447, DCE-GD-0084, Revision 1, 30th March 2017 (Ref.28)	ALARP Review of Potential Risk Reduction Measures on UK ABWR Decommissioning
GA91-9201-0003-01347, DCE-GD-0082, Revision 1, 30th March 2017 (Ref.29)	Dose Rate and Radiological Consequence Assessment for Major Decommissioning Activities
GA91-9201-0003-01325, DCE-GD-0080, Revision 0, November 2016 (Ref.30)	Supporting Document on Decommissioning: Decontamination Strategy
GA91-9201-0003-01150, XE-GD-0546, Revision 0, 28th September 2016 (Ref.31)	Response to RWM Assessment Report on UK ABWR Waste and Spent Fuel Disposability
GA91-9201-0003-00425, WE-GD-0050, Revision 3, July 2017 (Ref.32)	Integrated Waste Strategy

GA91-9201-0001-00253, XE-GD-0706, Revision 1, 31st May 2017 (Ref.33)	Topic Report: CDM Compliance (Response to RQ-ABWR-1184)
GA91-9201-0003-01347, DCE-GD-0082, Revision 1, 30th March 2017 (Ref.34)	HAZOP Report Supporting Document: Dose Consequence Assessment for Major Decommissioning Activities on UK ABWR
GA91-9201-0003-01231, HE-GD-5192, Revision 2, 5th August 2016 (Ref.35)	Contamination Control Philosophy
GA91-9201-0003-00698, XE-GD-0419, Revision 5, 25th July 2017 (Ref.36)	OPEX Report for UK ABWR
GA91-9201-0003-01348, DCE-GD-0083, Revision 1, 30th March 2017 (Ref.37)	Main Faults and Fault Groupings – Activities within the decommissioning phase on the UK ABWR
GA10-0511-0004-00001, XD-GD-0037, Revision 1, 2nd December 2015 (Ref.38)	GDA ALARP Methodology

36. Decommissioning requires close integration between matters of safety and environmental protection, within which the consideration of options should take account of both the on-site and off-site contributors to risk, to arrive at an overall solution that complies with the principles of Best Available Techniques (BAT) and maintaining risks as low as reasonably practicable (ALARP). Importantly, the Topic Reports on decommissioning supported both the safety claims made in the PCSR and environmental claims made in Hitachi-GE's case for the Generic Environmental Permit (GEP), as shown in Figure 1.

Figure 1
Relationship between the Safety and Environmental Cases for Decommissioning*



3.1 Generic PCSR Chapter 31

37. Chapter 31 of Hitachi-GE's PCSR provided a high-level overview of the Requesting Party's safety case for decommissioning and included 5 safety claims and 21 sub-claims. The main elements of the case were:

- Decommissioning strategy.

* This figure was copied from Ref.25 and therefore the references shown do not apply to this Assessment Report, but to the document from which it was taken.

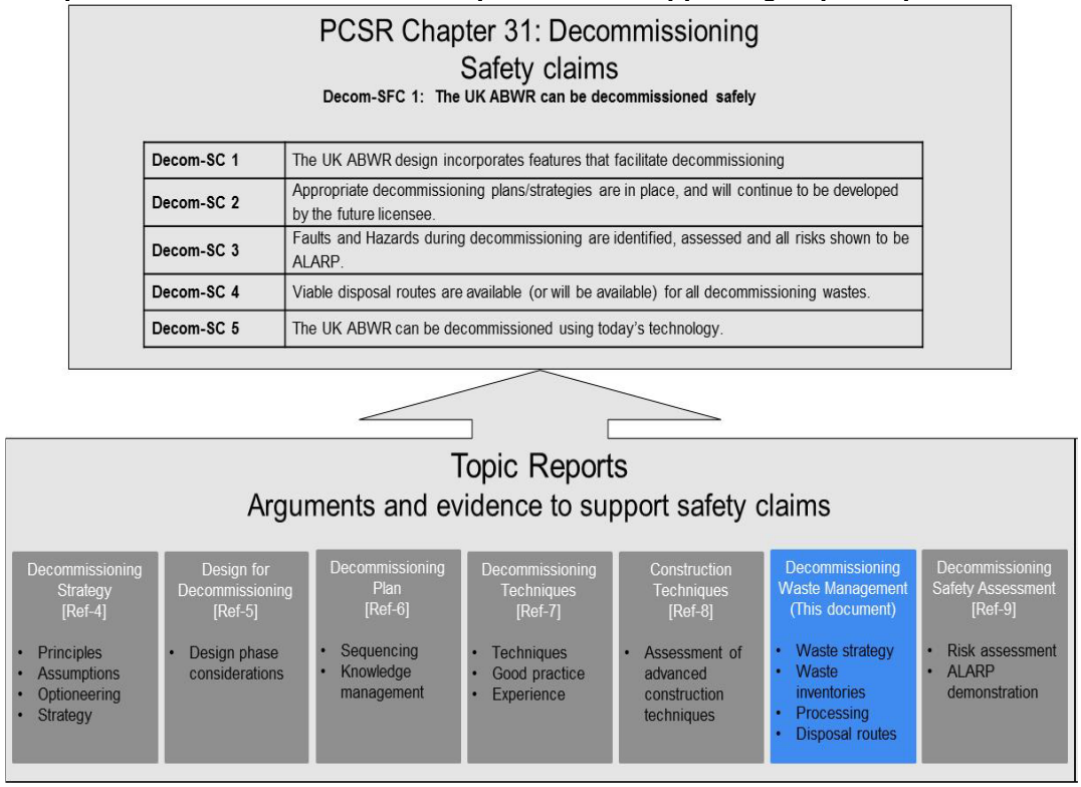
- Decommissioning plan.
- A consideration of Operational Experience (OPEX).
- Design for decommissioning.
- Analysis of key decommissioning tasks, associated design features and identification of candidate decommissioning techniques.
- Management of decommissioning wastes.

38. The 5 top-level claims pertinent to decommissioning were:

- Decom-SC 1: The UK ABWR design incorporates features that facilitate decommissioning.
- Decom-SC 2: Appropriate decommissioning plans/strategies are in place and will continue to be developed by the future licensee.
- Decom-SC 3: Faults and hazards during decommissioning are identified, assessed and all risks shown to be ALARP.
- Decom-SC 4: Viable disposal routes are available (or will be available) for all decommissioning wastes.
- Decom-SC 5: The UK ABWR can be decommissioned using today's technology.

39. Arguments and evidence to support the above claims were provided in seven underpinning Topic Reports and their supporting references, in accordance with the structure shown in Figure 2.

Figure 2
Relationship Between Claims in PCSR Chapter 31 and Supporting Topic Reports†



† This figure is copied from Ref.25 and therefore the references shown do not apply to this Assessment Report, but to the document from which it was taken.

40. The PCSR acknowledged the need for a future operator of a UK ABWR to carry out further work on decommissioning as part of site-specific developments. This included implementation of specific design features of importance to decommissioning in the UK ABWR detailed design, where Hitachi-GE believed it was not proportionate to develop the design to a sufficient level to demonstrate their full adoption within GDA.

41. As well as identifying a baseline of currently available techniques that are capable of decommissioning each area of the UK ABWR, Hitachi-GE sought to demonstrate the design will allow a future licensee flexibility to adopt alternative decommissioning methods if it sees fit.

42. In light of the unavoidable uncertainties that are inherent to the consideration of decommissioning within GDA, it was necessary for Hitachi-GE to make a series of assumptions within its safety case. These assumptions concerned both on-site and off-site factors (such as the availability of disposal routes for decommissioning wastes).

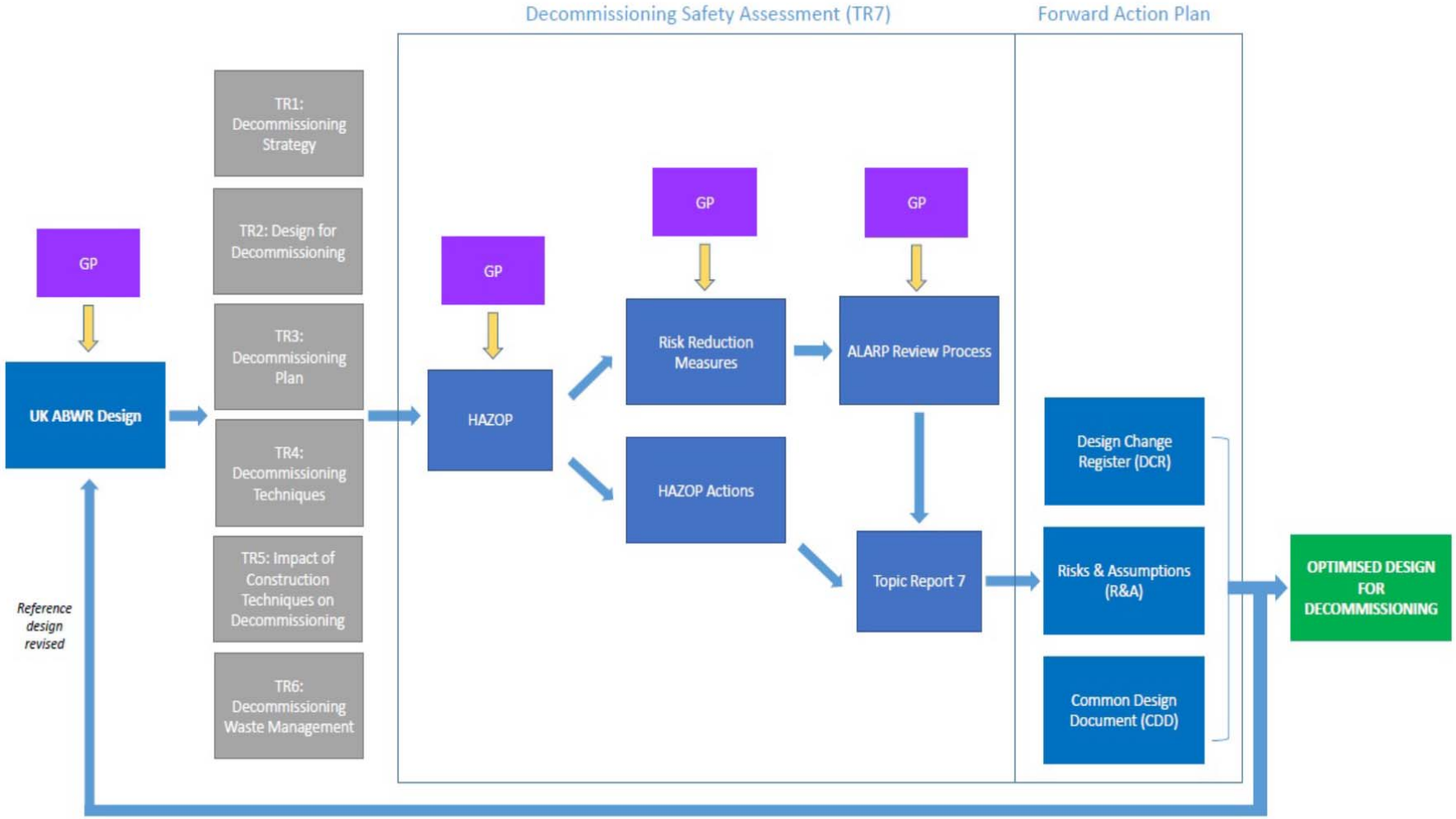
43. Chapter 31 also summarised Hitachi-GE's consideration of global decommissioning OPEX, which included:

- Identification of techniques that have been applied to specific elements of nuclear power plant decommissioning globally
- Typical risks encountered during decommissioning
- Lessons learned from difficulties encountered during decommissioning of older nuclear power stations globally, such as the early generation Boiling Water Reactors (BWRs), and other nuclear facilities

44. Through its analysis of OPEX, Hitachi-GE sought to demonstrate that its strategy and plan could be delivered via mature technologies that have already been applied to nuclear decommissioning in situations similar to those expected on the UK ABWR.

45. To demonstrate that the UK ABWR design, decommissioning strategy, plan and techniques have all been challenged in a comprehensive and systematic manner to ensure that the risks of future decommissioning can be reduced ALARP, Hitachi-GE integrated the component parts of its decommissioning case in accordance with the structure shown in Figure 3.

Figure 3
Contribution of Hitachi-GE's key Submissions to an Optimised Design for Decommissioning



3.2 Decommissioning Topic Reports

Topic Report 1: Decommissioning Strategy

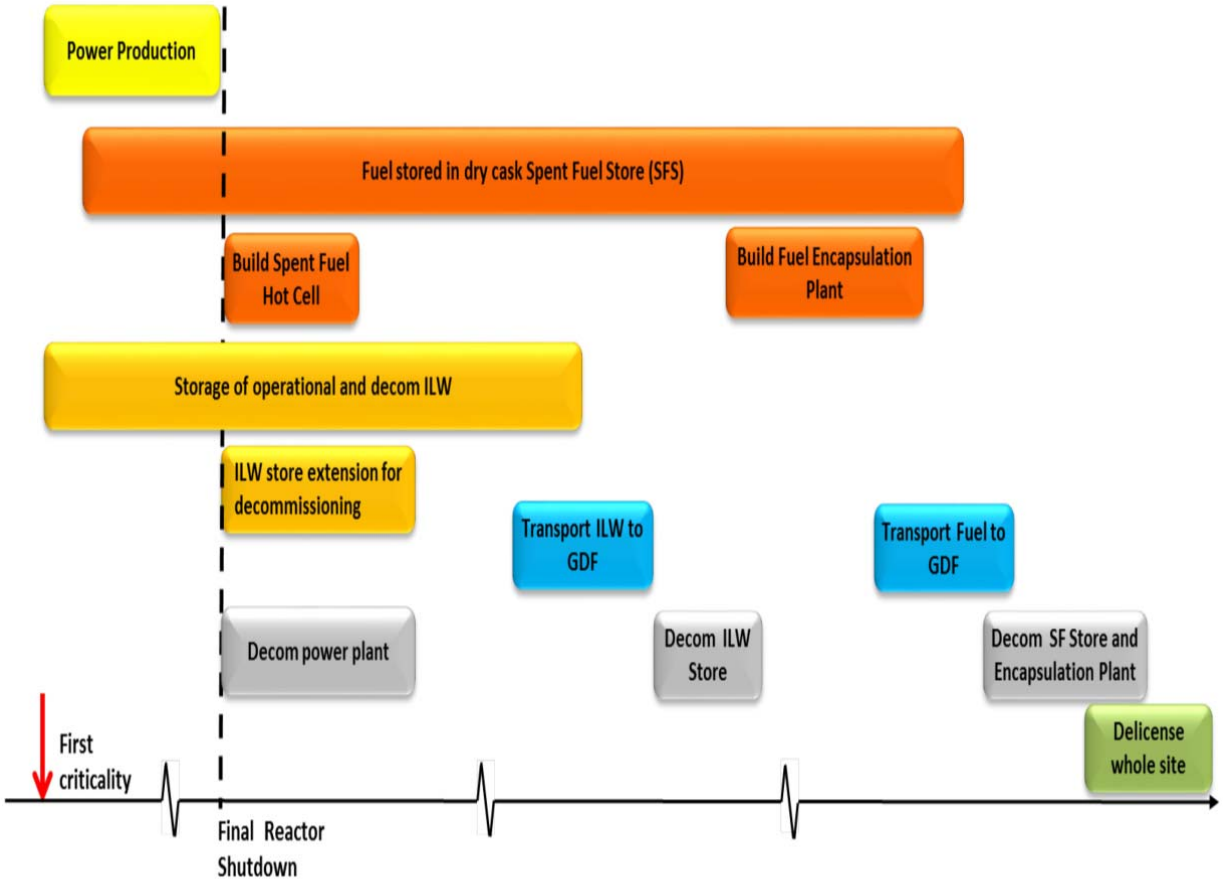
46. This Topic Report provided a central part of Hitachi-GE's arguments and evidence to support claim Decom-SC 2: *"Appropriate decommissioning plans / strategies are in place, and will continue to be developed by the future licensee"*.

47. Hitachi-GE initially identified four candidate decommissioning strategies. The strengths and weaknesses of these four options were considered against a list of relevant factors and scored, with the result that prompt dismantling was selected for application to the UK ABWR.

48. The report explained the process by which Hitachi-GE identified that prompt dismantling, to the point where the site is delicensed, was its preferred decommissioning strategy. This strategy had the following main steps:

- Before the 'End of Generation' date.
- Immediately after the 'End of Generation' date.
- Power plant decommissioning.
- Spent Fuel and Higher Activity Waste storage.
- Higher Activity Waste store emptying, repackaging, and disposal.
- Spent Fuel storage, followed by store emptying, repackaging and disposal.
- Demolition and delicensing of the site.

Figure 4
Key Activities in Hitachi-GE's Prompt Dismantling Strategy



49. Hitachi-GE's consideration of decommissioning options reflected the following constraints, which were aligned with the UK Government's Base Case guidance:

- A single reactor operating for 60 years (noting that the Base Case assumes an operating life of 40 years, whilst the government's guidance explicitly recognises that most current station designs have a design life of 60 years and operators are at liberty to justify alternative station lifetimes).
- Decommissioning will be carried out using current technology
- Spent fuel will not be reprocessed and will therefore need to be safely stored on the licensed site until being disposed of in the planned GDF
- At the completion of decommissioning, all buildings will be demolished and the site delicensed

50. Table 1 of the Decommissioning Strategy provided strategic level assumptions against several themes, that concerned:

- The scope and sequence of decommissioning.
- Status of the UK ABWR at the commencement of decommissioning.
- Availability of off-site disposal routes for radioactive wastes.

51. The Topic Report also listed 14 key principles of decommissioning, with the relevance of each principle to specific pieces of regulatory guidance highlighted.

52. Hitachi-GE acknowledged that developments in technology and emergence of new information prior to the start of decommissioning may give rise to a need for the strategy to be changed. Hitachi-GE therefore sought to demonstrate that the UK ABWR design does not foreclose a future licensee from adopting an alternative strategy should it see fit.

Topic Report 2: Design for Decommissioning

53. In this report Hitachi-GE provided evidence to demonstrate that the design of the UK ABWR gave due consideration to reducing the risks of its future decommissioning ALARP, via the following combination of measures:

- Decommissioning design principles.
- Identification of features in the UK ABWR design that are important facilitators of decommissioning.
- Development of a comprehensive baseline set of decommissioning techniques, based on current technology.
- A systematic and comprehensive challenge of the UK ABWR design, using an adapted HAZOP methodology, to identify reasonably practicable improvements to reduce the risks of future decommissioning.

54. Using lessons learned from past decommissioning projects, Hitachi-GE applied a systematic approach to identify where the reference design features will aid decommissioning, as well as opportunities to improve the design to reduce the risks and environmental impacts of decommissioning.

55. Specific design features recognised as having particular importance for decommissioning included materials selection, surface finishes, water chemistry control, ancillary services that will support decommissioning, containment of nuclear matter, capability to drain-down systems and processes, personnel access and space,

egress routes for large items, a reduction in the extent of embedded piping and long-term integrity of structures.

56. The design features identified within the report were either:

- Pre-existing within the reference design.
- Identified as a result of the design challenge process and incorporated into the UK ABWR design during GDA.

  or

- Features that formed part of the GDA 'reference design' but Hitachi-GE judged it was not proportionate during GDA to develop the design to a stage such that full evidence of their incorporation could be provided. These features were therefore carried forward to the site specific phase via the Requirements and Assumptions list, or in the form of decommissioning claims in the PCSR.

57. The report provided evidence to support the higher-level claims and arguments that the UK ABWR design incorporated features that facilitated decommissioning, can be decommissioned using current technology, minimise worker doses and waste generation and all associated risks will be reduced ALARP.

58. For those design features that will be finalised during the site-specific stage, the Requirements and Assumptions list was categorised and registered to ensure effective transfer of information between project phases. The list was reviewed to provide clarity about the actions required and when they should be delivered. The Requesting Party claimed that future close-out of all the Requirements and Assumptions will result in an 'as built' design that is optimised for decommissioning.

Topic Report 3: Decommissioning Plan

59. Topic Report 3 presented a high-level schedule to deliver prompt dismantling of the UK ABWR through a sequence of activities, within which the duration of each activity was estimated by:

- Applying production rates for the preferred decommissioning activities.
- Using operational experience from completed decommissioning projects (e.g. spent fuel pools).
- Plans generated from first principles by decommissioning specialists.

60. The plan consisted of the following phases:

- **Phase 1** - Detailed decommissioning pre-planning, obtaining the necessary regulatory approvals, starting approximately 5 years prior to the station's End-of-Generation date.
- **Phase 2** - From the point when the UK ABWR is shut-down until the Spent Fuel Pool has been emptied of its inventory. Therefore the start date of Phase 2 will be aligned with the station's End-of-Generation date.
- **Phase 3** - From the point where all spent fuel has been transferred out of the Reactor Building into dry cask interim storage, up until demolition of all the buildings in the main power production area of the site. For the purposes of GDA, the assumed start date for Phase 3 is 10 years after the End-of-Generation date.
- **Phase 4 and 5** - On-site storage of packaged spent fuel and Higher Activity Waste, up until the point where all the Higher Activity Waste is consigned off-site for disposal to the UK GDF.

- **Phase 6 and 7** - Inspection, repackaging, and consignment off-site of spent fuel to the GDF, followed by the final phase of demolition and delicensing of the site. The timing of Phase 6 is dependent on the readiness of a UK-based GDF to accept new build spent fuel, noting that NDA RWM Ltd has advised that spent fuel from new build reactors may not be accepted until 2146, with transfers assumed to be completed by 2190.

61. However the following statement was made in RWM Ltd's assessment of the disposability of the expected UK ABWR spent fuels (Ref.39), "*Based on the thermal modelling done as part of the design impact assessment, disposal of spent fuel from a UK ABWR to a geological disposal facility in higher strength rock could commence from 2131. This would allow the spent fuel to be readily incorporated into a disposal schedule consistent with the current assumption of closure of a geological disposal facility commencing in 2190*."

62. In the final version of Hitachi-GE's decommissioning plan Phase 4 was merged with Phase 5, and Phase 6 was merged with Phase 7 to provide a future licensee with greater flexibility in its schedule with respect to the availability of the planned GDF.

Topic Report 4: Decommissioning Techniques

63. This report identified a set of currently available dismantling, decontamination and demolition techniques to provide a baseline for decommissioning all the constituent areas of the UK ABWR. By doing so the report provided arguments and evidence in support of claim Decom-SC 5: *"The UK ABWR can be decommissioned using today's technology"*.

64. The techniques were identified from a consideration of a broad range of past or current nuclear decommissioning projects, on early generation BWRs and other types of nuclear facilities in the UK and internationally, with perceived similarities with the circumstances of the UK ABWR.

65. Important objectives of the document were:

- To demonstrate the technical feasibility of decommissioning the UK ABWR via a strategy of prompt dismantling, using current technology.
- To identify preferred techniques and their production rates, to allow activity durations to be estimated in the Decommissioning Plan.
- To establish a baseline for analysis of decommissioning hazards and risks, as an input to the Decommissioning Safety Assessment.

66. The report did not identify a detailed decommissioning technique for every individual plant item. With the exception of major decommissioning activities (e.g. Reactor Pressure Vessel segmentation), similar plant and equipment were grouped together and a single technique (or family of similar techniques) was applied to each group.

67. The initial baseline of techniques was fed into an iterative safety assessment process, described in Topic Report 7, within which the UK ABWR design was challenged in order to reduce decommissioning risks ALARP. This brought about a need for some of the baseline techniques to be updated, in response to consequential alterations to the design.

68. The report acknowledged that many factors relevant to decommissioning were unavoidably subject of large uncertainties during the early stages of design. The report therefore presented 30 key assumptions which addressed areas such as anticipated plant conditions on the UK ABWR at the end of the operational phase, management of spent fuel, the site end state and the decommissioning sequence.

Topic Report 5: Impact of Construction Techniques on Decommissioning

69. In Topic Report 5 Hitachi-GE acknowledged the potential for advanced construction techniques, which were used extensively in the construction of the existing ABWRs in Japan, to be used in building the UK ABWR.

70. In particular, the Japanese ABWRs were built with extensive use of modular construction, open top construction, parallel construction and floor packaging construction. Perceived benefits of these techniques include reduced construction timescales, levelling of the resource requirements during construction, reduced conventional safety risks during construction and the capability to install pre-qualified large modules of plant and equipment.

71. The report considered ways in which advanced construction techniques may increase the risks or complexity of decommissioning (e.g. by restricting egress routes for large items, or creating contamination traps). Where potential dis-benefits were identified the report suggested possible mitigations, such as changes to the plant layout, in order that the constraints of advanced construction techniques could be accommodated without increasing the risks of decommissioning.

72. To provide a holistic overview of all relevant risks, the report also considered some perceived safety benefits of advanced construction techniques for the preceding stages of building and operating the UK ABWR.

73. As the ultimate choice of construction method will be the responsibility of a future licensee, key outputs from this Topic Report were summarised in a Forward Action Plan in order that further consideration will be given to this matter during the site specific phase of design.

Topic Report 6: Decommissioning Waste Management

74. This Topic Report presented Hitachi-GE's strategy for managing all the radioactive and non-radioactive wastes (in solid, liquid and gaseous forms) expected to arise during decommissioning. The report aimed to demonstrate:

- All decommissioning wastes were identified and understood.
- Feasible waste management solutions had been identified, based on existing processing techniques and existing or planned UK disposal routes.
- Application of good practices in waste management, recognising the UK's approach to waste categorisation and the principles of the waste hierarchy (e.g. waste avoidance, minimisation and segregation).
- Compatibility of the approach to managing decommissioning wastes with the overall UK ABWR decommissioning strategy, plan, techniques and associated safety assessments.
- Technical viability of the intended waste management routes, in light of the unavoidable uncertainties in the properties of the decommissioning wastes that are not expected to arise until after the station's End-of-Generation date.

75. The report explained how Hitachi-GE generated a decommissioning end-user source term as an estimate of the amount and type of radioactive species that will be present in the UK ABWR systems at the time when decommissioning will take place.

76. The report identified a series of design features whose performance throughout the operational phase will be important to minimising the extent of decommissioning required at the end of the station's life, such as materials selection, contamination control, fuel design and control of coolant chemistry.

77. The report recognised the benefits of carrying out decontamination on the UK ABWR systems prior to decommissioning and considered the opportunity for decontamination to enable certain decommissioning wastes to be disposed of at a lower categorisation

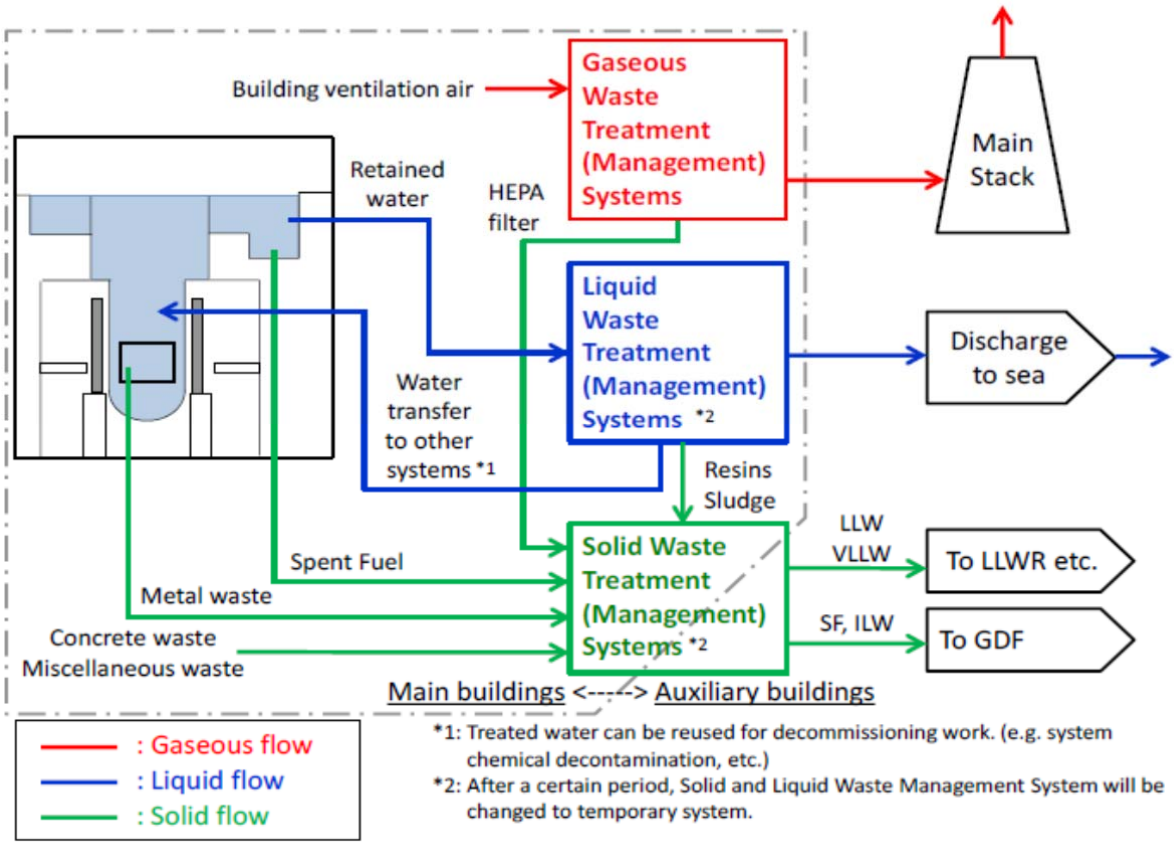
(typically ILW that has potential to be decontaminated to LLW). Importantly, the report also considered potential dis-benefits of decontamination processes, such as increased worker doses from manual methods of decontamination and creation of secondary wastes.

78. In addition to identifying the anticipated types of decommissioning wastes, the report also presented the timescales on which each waste stream was expected to arise. This data informed a consideration of the need to provide bespoke waste management facilities after the end-of-generation specifically to meet the needs of decommissioning, via which Hitachi-GE identified the need to provide the following additional systems:

- A temporary Liquid Waste Management System, due to the Radwaste Building being taken out of service and significant changes to the volumes and characteristics of the liquid effluents being generated.
- A Decommissioning Waste Management Facility.
- A Fuel Repackaging Facility (FRF) incorporating a hot cell, local to the spent fuel interim store, to provide the site with ongoing capability to inspect and repack spent fuel and High Level Wastes after the SFP is taken out of service.

79. The Topic Report recognised the need for a future operator to iterate the strategy for managing decommissioning wastes, informed by more detailed understanding of the plant conditions, applicable standards, waste disposal routes and developments in good practice nearer the time when the station reaches the end of its operational life.

Figure 5
Overview of the UK ABWR Decommissioning Radioactive Waste Generation, Treatment and Disposal



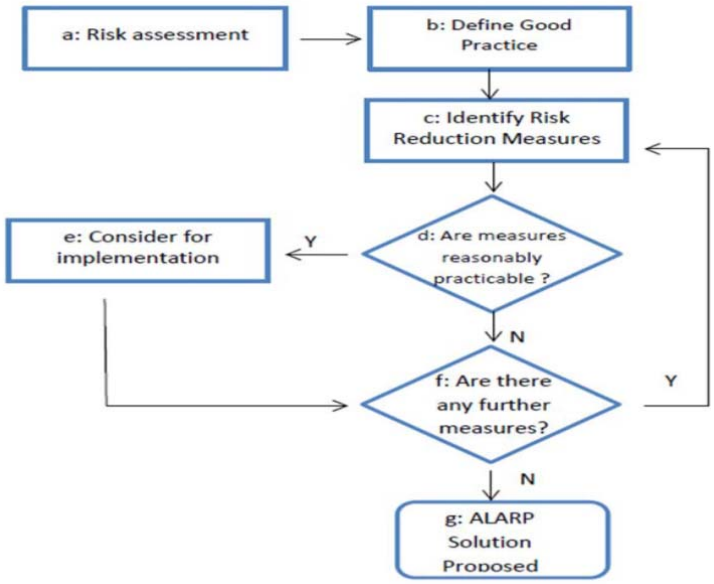
Topic Report 7: Decommissioning Safety Assessment

80. The main purpose of Hitachi-GE's decommissioning safety assessment was to systematically review the UK ABWR design and the proposed decommissioning techniques, to assess whether design changes were required to reduce the future challenges and risks of decommissioning so far as is reasonably practicable (SFAIRP).

81. In order to achieve this and arrive at an optimised design for decommissioning, Hitachi-GE went through the following steps:

- Application of decommissioning good practices, taken from earlier evolutions of BWRs, lessons learned from decommissioning of similar reactor designs and other types of nuclear facilities.
- A modified Hazard and Operability (HAZOP) process, which was adapted to provide a systematic and comprehensive challenge of the design and identify opportunities to reduce the hazards and risks of future decommissioning through a process of design change. Although HAZOP studies are traditionally used in the initial identification of hazards, in this case Hitachi-GE added two criteria in order that the process delivered a challenge to the UK ABWR design. These criteria were:
  - Design Features – to identify features that were already included within the reference design which will play an important role in supporting future decommissioning
  - Design Change Considerations – to identify the potential for changes or modifications to be made to the reference design that may further reduce the challenges and risks of future decommissioning
- Identification of the main types of design basis faults associated with decommissioning, with estimated risks for 12 main fault groups. The assessment of risk was based on dose calculations, focussed on the decommissioning activities that had the greatest likelihood of providing a high dose to an operator.
- An ALARP review, carried out in accordance with Hitachi-GE's GDA ALARP Methodology (Ref.31, summarised in Figure 6) to assess whether the potential design changes identified during the adapted HAZOP process were reasonably practicable to implement. This included Hitachi-GE's consideration of the overall impact of potential design changes, to ensure that the perceived benefits to decommissioning were not outweighed by any difficulties of implementation or any other detriment (principally to the UK ABWR operational philosophy).
- Outputs were then sentenced for implementation via a Forward Action Plan that contained the Design Change Register, Requirements and Assumptions list and Decommissioning Safety Claims.

Figure 6
Hitachi-GE's GDA ALARP Methodology



82. Hitachi-GE provided evidence that the HAZOP process involved suitably qualified and experienced representatives from a wide range of engineering disciplines and recognised Subject Matter Experts in Decommissioning and took place in two steps; an initial desktop study followed by a HAZOP 1 exercise.

83. The HAZOP process applied 19 keywords to the decommissioning of 25 key areas of the UK ABWR plant. Major findings included:

- Optimisation of export routes for decommissioning – to reduce the required number of nuclear lifts during de-planting.
- Removal of large contaminated vessels whole – to reduce the need for workers to undertake prolonged segmentation in confined spaces.
- Safety features for decommissioning – a number of areas were identified with the potential to increase safety margins and provide greater flexibility to the future licensee during decommissioning.
- Sequencing – it was recommended that the sequence of de-planting should minimise the need to undertake lifting operations with hoisted components traversing over vulnerable equipment.
- Removal of embedded pipework – the HAZOP identified several hazards associated with removal of pipework and potential radiological consequences in the event of a breach of containment.
- Conventional safety – opportunities were identified to remove or reduce conventional safety risks to workers, primarily associated with segmentation and lifting operations.

84. Appendices to Hitachi-GE's Topic Report on Safety Assessment summarised the HAZOP study outputs in order to demonstrate that the UK ABWR design will incorporate all the identified measures that were judged to reduce the challenges and risks of future decommissioning SFAIRP.

3.3 Other Supporting Documents

HAZOP Report – Activities within the Decommissioning Phase on UK ABWR

85. This document contained a detailed description and auditable record of the adapted HAZOP study that supported Topic Report 7 (see above) and demonstrated that all of the identified HAZOP actions had been closed.

Main Faults and Fault Groupings – Activities within the decommissioning phase on the UK ABWR

86. This report tabulated the main fault groups associated with decommissioning that were identified in Topic Report 7, together with estimated radiological consequences and mitigating design features. The main fault groups were:

- Decontamination, cutting, unbolting and removal operations involving direct worker contact resulting in radiological / conventional hazard.
- Remote decontamination, cutting, unbolting and removal operations resulting in radiation doses to workers.
- Contaminated wounds.
- Loss of containment of contaminated water, oils or liquors.
- Loss of ventilation resulting in increased aerosol concentration and spread of contamination.
- Dropped loads / impacts.
- Fire / explosion.
- Radiation doses during waste transfers.
- Access restrictions.
- Radiation doses as a result of exposure to contaminated resins.

Contamination Control Philosophy

87. In this report Hitachi-GE provided guidance on the control of radioactive contamination throughout all lifecycle phases of the plant, incorporating case studies of good practices during decommissioning.

OPEX Report for UK ABWR

88. This report presented a collection of OPEX from a wide range of nuclear facilities around the world and included frequent references to decommissioning that were input to Topic Report 4.

Disposability Assessment for Wastes and Spent Fuel – RWM Limited

89. In accordance with the GDA Guidance to Requesting Parties (Ref.2), during GDA Hitachi-GE engaged RWM Ltd to assess the disposability of the Higher Activity Wastes (HAW) and spent fuels expected to arise through the lifetime of the UK ABWR within the UK's planned GDF.

90. This report presented the outcomes of RWM's assessment (Ref.39), which included a consideration of the following two main types of HAW (Ref.41) that will arise during decommissioning:

- Reactor Pressure Vessel Internals, consisting of in-vessel stainless steel structures that support the reactor core and its safety systems, and manage the flow of coolant into and out of the core.

- The Reactor Pressure Vessel structure itself, consisting of the low alloy steel outer vessel with stainless steel cladding for which Hitachi-GE proposed cement encapsulation in 4-metre Boxes with 200-mm concrete walls for shielding.

91. The anticipated decommissioning HAW also comprised a small volume of stainless steel filter housings.

92. RWM Ltd reported activities in similar present-day UK wastes, normalised the data to facilitate a like-for-like comparison, then showed that the radionuclide contents expected to occur in the UK ABWR waste streams was comparable to those from the pre-existing Pressurised Water Reactor at Sizewell B.

93. From its assessment of Hitachi-GE's data, RWM Ltd identified 27 areas for further consideration (23 relating to management of ILW and 4 relating to spent fuel), none of which were considered to challenge the fundamental disposability of the UK ABWR wastes and spent fuel.

94. RWM Ltd therefore concluded that the HAW and spent fuel expected to arise from both the operation and decommissioning of a UK ABWR should be compatible with off-site transport and geological disposal at the UK's planned GDF.

95. Therefore, given a disposal site with suitable characteristics, the wastes and spent fuel from the UK ABWR are expected to be disposable.

4 ONR STEP 4 ASSESSMENT

96. This assessment was carried out in accordance with ONR's internal assessment standards and guidance, including the 'Purpose and Scope of Permissioning' (Ref.40).

97. During the early stages of Step 4, decommissioning proved to be a challenging topic for Hitachi-GE due to a number of influential factors, for example:

- The concept of 'design for decommissioning' was not applied to the earlier generations of BWRs and the J-ABWR, from which the UK ABWR design evolved.
- No ABWR has yet been decommissioned.
- Management of the radioactive wastes arising from decommissioning is subject of many UK-specific policies, standards and constraints, such that the established methods in Japan would not be recognised good practices in the context of the UK ABWR.
- The need to distinguish between the different purposes of the UK's safety-focussed legislation (primarily to ensure risks to safety are demonstrably reduced ALARP) and The Energy Act 2008 (to ensure operators make prudent financial provisions for decommissioning).

98. However by the end of Step 4 Hitachi-GE made considerable progress and demonstrated a greatly improved appreciation of UK expectations for decommissioning in a suite of revised safety case submissions provided to the regulators.

4.1 Scope of Assessment Undertaken

99. During Step 4, ONR has:

- Assessed all the submitted revisions of the Hitachi-GE documents listed in Table 3 of this report.
- Requested and assessed additional detailed references from Hitachi-GE.
- Held technical discussions in Level 4 meetings with Hitachi-GE.
- Provided advice and guidance to Hitachi-GE on ONR's expectations for an adequate consideration of decommissioning within GDA.
- Raised 17 Regulatory Queries (RQs) (see Annex 4).
- Assessed the adequacy of Hitachi-GE's responses to the 17 RQs.
- On a multi-disciplinary basis considered the inter-linkages between Hitachi-GE's decommissioning submissions and other parts of the UK ABWR safety case.

100. No Regulatory Issues (RIs) or Regulatory Observations (ROs) were raised directly against Hitachi-GE's decommissioning submissions during Step 4. However decommissioning was a relevant consideration to an RI and several ROs that were raised in other assessment disciplines during GDA – these are listed in Annex 5 and summarised in Section 4.3 and 4.4.

101. In accordance with ONR's Guidance to Requesting Parties (Ref.2), residual matters were recorded as GDA Assessment Findings if one or more of the following applied:

- Resolution of the matter required site-specific information.

- Resolution of the matter depended on licensee design choices.
- The matter related to other licensee-specific features / aspects / choices associated with future operational philosophy.
- Resolution of the matter required a greater level of detail on the design than can reasonably be expected in GDA.
- Resolution of the matter was not practicable until the plant enters the phases of construction or commissioning.

102. Decommissioning a nuclear power station involves a wide range of radiological and conventional safety hazards. Priorities for ONR's scrutiny were informed by the key principle of ONR's Enforcement Policy Statement – that the requirements of safety should be applied in a manner that is commensurate with the magnitude of the hazard. Therefore during this assessment ONR targeted the features of the UK ABWR that were of greatest relevance to the hazards and risks of future decommissioning.

103. The specific evidence sought by ONR included:

- A demonstration that the design complies with the expectations of UK law, policies and regulatory standards applicable to nuclear decommissioning and management of the wastes expected to arise from decommissioning.
- A clearly defined and adequately documented decommissioning strategy and plan.
- A demonstration that Hitachi-GE's proposals for decommissioning are deliverable using current technology.
- Justification of significant assumptions, to demonstrate that Hitachi-GE had adopted a precautionary approach to the uncertainties that are inherent to the consideration of decommissioning during the early stages of design.
- Challenge of specific design features, targeted on areas of the plant that will give rise to the greatest hazards and risks of future decommissioning.
- A demonstration that the intended operational regime had been challenged to reduce the hazards and risks of future decommissioning ALARP.
- Arrangements to ensure any significant impacts on decommissioning are taken into account during design changes and process modifications.
- A demonstration that the design will allow a future licensee to deploy an appropriate hierarchy of hazard control measures during decommissioning, in respect of the principles of Eliminate, Reduce, Isolate, Control, Personal Protective Equipment and Discipline (widely known as 'ERIC–PD').
- A demonstration that all Systems, Structures and Components (SSCs) expected to play a role in future decommissioning can realistically meet the duties claimed of them, in terms of both functionality and length of service.
- Clear and traceable links between underpinning data, Topic Reports, the generic PCSR and other parts of the safety case which concern the engineering of relevant SSCs.

4.2 Assessment

Decommissioning Strategy and Plan

104. ONR's high-level expectations for decommissioning strategies and plans are highlighted in the SAPs, with a greater level of detail provided in a dedicated Technical Assessment Guide. International standards and UK Government policy also refer to the need for decommissioning strategies and plans.

105. In order for Hitachi-GE to meet UK expectations, its strategy and plan needed to; provide a clear definition of the scope and intended goals of decommissioning; explain any relevant constraints, and; set the context for how decommissioning will be practically delivered.

106. To achieve this, ONR expected that the decommissioning strategy should contain:

- A clear definition of the intended end state for decommissioning.
- The process by which the strategic options for decommissioning were selected.
- How interdependencies were taken into account.
- Arrangements for keeping the decommissioning strategy and plan up-to-date.

107. Hitachi-GE's target end state for decommissioning is delicensing of the site, such that a future licensee will have the opportunity to close its period of responsibility under NIA65 at the appropriate time. Hitachi-GE recognised that achievement of delicensing currently requires UK licensees to objectively demonstrate that 'no danger' remains from ionising radiations anywhere on the site at the end of decommissioning and referenced the appropriate regulatory standards. Elsewhere within its safety case Hitachi-GE also recognised the need for modifications to the design to make it compatible with achievement of 'no danger' including a reduction in the extent of embedded pipework.

108. Within its Decommissioning Strategy Topic Report Hitachi-GE provided an open and transparent description of the process undertaken to select its strategic approach, which consisted of:

- Identification of four high-level strategic options (i.e. prompt dismantling, deferred dismantling of ILW, deferred dismantling of all radiological systems and entombment).
- The four options were developed to a level of detail sufficient to allow a judgement on their relative merits.
- Entombment was discounted, due to it being incompatible with international standards and UK expectations.
- The remaining three options were scored against a list of relevant factors, by an expert team that contained suitably qualified and experienced persons, resulting in prompt dismantling being selected as the preferred strategy for decommissioning the UK ABWR.

109. By adopting a strategy of prompt dismantling with an end point of delicensing, Hitachi-GE aligned its proposals with the expectations of the UK regulators and government policy.

110. Throughout Step 4 ONR sought assurance that Hitachi-GE had adopted a precautionary approach to the uncertainties that are inherent to the consideration of decommissioning during the early stages of design. Hitachi-GE demonstrated that its choice of strategy was robust to the potential uncertainties associated with 23 relevant assumptions (that were grouped into 11 themes) in the Decommissioning Strategy Topic Report.

111. Although Hitachi-GE's proposal for prompt dismantling was consistent with the UK Government's Base Case strategic assumptions for new nuclear power stations, RQ-ABWR-1125 was raised to seek assurance that the UK ABWR civil structures will be capable of delivering their safety functions for an extended period, should the timescales of decommissioning have to be extended for any reason. Hitachi-GE responded that the UK ABWR has been designed to ensure long-term structural integrity for decommissioning purposes, including in the event that demolition is delayed. However the requirement for the structural design to have longer-term integrity for decommissioning purposes was formally captured by Hitachi-GE as a forward action for a future licensee to address during site-specific detailed design.

112. This matter has therefore been captured within **Assessment Finding AF-ABWR-D-01** (see Annex 6), as its resolution requires operator-specific features / aspects / choices.

113. Throughout Step 4 ONR also challenged other specific parts of Hitachi-GE's decommissioning strategy and plan, to investigate whether further worthwhile opportunities existed to reduce hazards and risks. Within its assessment of Spent Fuel Interim Storage (Ref.8), ONR has raised an Assessment Finding to ensure that the UK ABWR design will not foreclose options to reduce the need for loaded Multi-Purpose Containers to be removed from the store and taken back to the Spent Fuel Pool for the purpose of fault recovery.

114. From this section of its assessment, ONR was able to conclude that Hitachi-GE had satisfied regulatory expectations in respect of the proposed decommissioning strategy and plan for the UK ABWR, in particular:

- Hitachi-GE had developed a decommissioning strategy and plan for the UK ABWR, based on prompt dismantling after the reactor's 60-year operating life, which aligned with UK law, was compatible with UK Government policy and met the expectations of the UK regulators.

- Hitachi-GE's intended end-point for decommissioning of the UK ABWR was for the site to be delicensed and Hitachi-GE had taken steps to ensure that the design was compatible with achievement of that objective.

Decommissioning Safety Assessment and Design for Decommissioning

115. Hitachi-GE's Topic Report on Design for Decommissioning, "*summarises design features for decommissioning, and provides the evidence, or links to the evidence, to demonstrate that they have been incorporated into the UK ABWR design and consequently demonstrate that the UK ABWR meets the required standards for decommissioning*". ONR challenged Hitachi-GE as to whether the UK ABWR design included all reasonably practicable opportunities to:

- Reduce the scale and difficulty of the decommissioning that will be required at the end of the station's operational life, and;

- Incorporate design features to enable the required decommissioning activities to be carried out without unnecessary risks.

116. I raised a series of RQs that asked Hitachi-GE for further evidence to demonstrate that it had a systematic, comprehensive, objective, open and transparent process in place to identify opportunities to reduce the risks of future decommissioning and evaluate if any of those opportunities were reasonably practicable to implement.

117. ONR's overarching expectations for optimisation of the UK ABWR design in respect of decommissioning were contained in RQ-ABWR-0825 and followed up in RQ-ABWR-0833 (Optimisation of Future Commitments) with some highlighted specific examples in RQ-ABWR-0826 (Decommissioning of Large Items).

118. In order to address my concerns, Hitachi-GE introduced a HAZOP exercise into its Decommissioning Safety Assessment. During the HAZOP process Hitachi-GE identified several opportunities to reduce the hazards and risks of future decommissioning, which included:

- Potential to segment the Reactor Pressure Vessel underwater.
- Improved egress routes out of the Reactor Building for decommissioning wastes – by reducing the required number of nuclear lifts and overall export pathway.
- Improved egress routes to allow large contaminated items to be exported whole – to enable their size reduction, where necessary, to take place remotely in a centralised specialist facility (in preference to operators having to undertake lengthy de-planting work within confined spaces).
- Safety features for decommissioning – a number of opportunities were identified to provide greater flexibility and support to the licensee during decommissioning, e.g. by adding lintels into the structural design to allow sections of walls to be safely removed at the end of the operational phase.
- Sequencing – it was recommended that de-planting of the turbine should adopt an approach which minimised the need to undertake lifting operations over vulnerable equipment.

119. Outputs from the HAZOP exercise were subject of an ALARP review, to establish whether the suggested design changes were reasonably practicable to implement. The qualifying considerations were then incorporated into a forward action plan that had three components:

- Design Change Register – changes in the design, that Hitachi-GE believed should be implemented unless a separate ALARP justification to the contrary could be made.
- Requirements & Assumptions list – items assumed to form part of the design, but carried forward to the site specific phase as the practical delivery will be provided by a future licensee.
- Common Design Document – a list of further considerations for the UK ABWR's future design stages, highlighted by Hitachi-GE for the attention of a future licensee.

120. ONR gave close scrutiny to each step of Hitachi-GE's design challenge process, due to its importance to the delivery of 'design for decommissioning'. ONR found that Hitachi-GE's initial reasoning for rejecting some of the suggestions made in the HAZOP was unclear. With a focus on the highest decommissioning risks, ONR raised RQ-ABWR-1173 (Potential Future Widening of the DSP/SFP Gates for the Purposes of Decommissioning) and RQ-ABWR-1177 (Potential to segment the Reactor Pressure Vessel (RPV) underwater during Decommissioning) to seek further explanation.

121. In its responses to RQ-ABWR-1173 and RQ-ABWR-1177, Hitachi-GE provided:

- A fuller explanation of the technical difficulties associated with the suggested design changes.
- International OPEX to better demonstrate the feasibility and safety of its intended approach to RPV segmentation and removal.
- A modified sequence and task logic for RPV segmentation, which would provide improved protection of workers and therefore addressed my concerns.

122. From this section of assessment I was able to conclude that Hitachi-GE's final set of GDA submissions contained an appropriate challenge to the UK ABWR reference

design and operating philosophy, such that the hazards and risks of future decommissioning can be reduced as low as reasonably practicable (ALARP).

Decommissioning Techniques

123. In order to meet UK expectations Hitachi-GE needed to demonstrate that the preferred decommissioning strategy of prompt dismantling was achievable using current technology. In assessing this aspect of Hitachi-GE's safety case, ONR's priorities were:

- To ensure Hitachi-GE had identified a comprehensive set of techniques, capable of delivering the full scope of required decommissioning activities.
- To ensure Hitachi-GE's selection of techniques was informed by current day relevant good practice, particularly lessons learned from decommissioning earlier generation BWRs.
- To ensure that the technical viability of Hitachi-GE's selected decommissioning techniques was not dependent on potentially optimistic assumptions on the way the UK ABWR will perform in practice.
- To ensure Hitachi-GE's selection of techniques gave due consideration to protection of workers, taking into account the risks that arise during decommissioning.

124. Within its Topic Reports, Hitachi-GE demonstrated that the scope of identified techniques was directly aligned with the decommissioning strategy and plan and was therefore comprehensive. This scope included the following types of activities:

- In-situ and ex-situ decontamination.
- Dismantling of the reactor, all reactor internals, control rods and other SSCs that directly support the reactor.
- Dismantling of pipework, tanks and vessels.
- Dismantling of other major plant items (e.g. turbine, heat exchangers and cranes).
- Management of decommissioning wastes.
- Final demolition and delicensing.

125. In respect of relevant good practice, Hitachi-GE presented a significant volume of information from case studies of decommissioning during Step 4, but without a sufficient explanation of how the case studies related to the circumstances of the UK ABWR, whether the quoted practices met ONR's expectations for relevant good practice nor how any lessons learned had been practically applied to improve the UK ABWR design. ONR therefore raised RQ-ABWR-1126, which asked Hitachi-GE to provide further evidence on:

- How the collated OPEX was relevant to the circumstances of the UK ABWR.
- Whether the claimed good practices took account of the current state-of-the-art.
- Ensuring the claimed good practices were not in the form of a minimum requirement.
- Where good practices or standards allowed for more than one option, the full range of alternatives had been tested.
- Applicability of the good practice to the specifics of the UK ABWR.
- Application of the principles of ALARP in design during adoption of RGP, wherein ONR expected to see evidence that all reasonably practicable steps had been taken to eliminate or avoid hazards in preference to relying on mitigation measures.

126. In response, Hitachi-GE provided a further explanation of:

- How it had practically collated the case studies and distilled lessons learned to apply them to the UK ABWR safety case for decommissioning.
- Inter-linkages between the OPEX report for the UK ABWR and the decommissioning submissions.
- Example lessons learned from a site visit to witness the decommissioning of the KKI-1 BWR at the Isar 1 site in Germany.

127. Hitachi-GE ultimately demonstrated that the adopted techniques were established and credible good practices, while acknowledging the likelihood of advances in technology prior to the time the UK ABWR is due to be decommissioned.

128. To demonstrate that its approach was based on mature current technology, Hitachi-GE required candidate techniques to have a minimum Technology Readiness Level (TRL) of 7 as defined by the NDA in its document EGG10 (Ref.41) - i.e. *'A full-scale, similar (prototypical) system to have been demonstrated in a relevant environment'*. TRLs provide an indication of the state of readiness of a technology to be applied for a specific purpose. NDA defined its scale of TRLs is shown in Table 4.

Table 4

NDA's Definition of Technology Readiness Levels (from Ref.41)

Relative Level of Technology Development	Technology Readiness Level	TRL Definition
System Operations	TRL9	Actual system operated over the full range of expected conditions
System Commissioning	TRL8	Actual system qualified through test and demonstration
	TRL7	Full scale similar (prototypical) system demonstrated in relevant environment
Technology Demonstration	TRL6	Engineering/pilot-scale similar (prototypical) system validation in relevant environment
	TRL5	Laboratory scale, similar system validation in relevant environment
Technology Development	TRL4	Component and/or system validation in laboratory environment
Research to prove feasibility	TRL3	Analytical and experimental critical function and/or characteristic proof of concept
	TRL2	Technology concept and/or application formulated
Basic Technology Research	TRL1	Basic principles observed and reported

129. Hitachi-GE added that the majority of selected techniques had the more advanced TRL9 – i.e. *'Actual system operated over the full range of expected conditions'* due to previous use on BWRs outside of the UK, or in the decommissioning of other types of nuclear facilities within the UK. However the report acknowledged that a TRL below 9 may apply in some cases, due to differences between the UK ABWR and the older BWRs that are presently being decommissioned in the USA and Germany. I judged this was an appropriate approach for the purposes of GDA.

130. Early versions of Hitachi-GE's Topic Report on Decommissioning Techniques listed 51 assumptions and it was important for these assumptions to have a robust basis.

131. ONR's SAPs and TAGs (including NS-TAST-GD-005 'Guidance on the Demonstration of ALARP') are consistent with, 'Reducing Risks, Protecting People: HSE's Decision-Making Process' (R2P2, Ref.42). Paragraphs 89 to 93 and Appendix 1 of R2P2 recommend the use of a precautionary approach to uncertainty, wherein precautions should be taken unless there is a good reason to think the identified risk is insignificant. It followed that for UK expectations to be met, Hitachi-GE needed to demonstrate a precautionary approach to uncertainty in its selection of decommissioning techniques, including a justification of key assumptions and the putting into place of precautionary options wherever significant design choices were sensitive to uncertainty.

132. It is particularly important to avoid any cliff-edge effects, which may occur if an inaccurate assumption leads to the intended decommissioning technique being unviable. Therefore ONR raised RQ-ABWR-1023, followed up by RQ-ABWR-1158, to scrutinise the basis of Hitachi-GE's assumptions.

133. In response, Hitachi-GE provided evidence on a case-by-case basis to claim that its assumptions either:

- Represented a conservative worst-case scenario, or
- Would not threaten the viability of the intended decommissioning techniques if they proved to be inaccurate.

134. For assumptions considered to represent a worst-case, Hitachi-GE believed any variation from the assumed condition would have a beneficial impact for decommissioning.

135. For assumptions assessed as having a low sensitivity for the UK ABWR design and decommissioning techniques, Hitachi-GE recognised a need for ongoing oversight and suggested this could be delivered as part of periodic reviews by a future licensee.

136. It is important that a future licensee applies a precautionary approach to uncertainty in its decommissioning strategy, plan and techniques that should reflect the final 'as built' design. ONR has raised an assessment finding within its consideration of MSQA to ensure that the future licensee shall establish a system of timely and regular reviews of the validity of all the assumptions that underpin the UK ABWR safety case, to reflect a precautionary approach to uncertainty and the choices made in detailed design.

137. ONR's final priority for this area of assessment was to ensure that Hitachi-GE's selection of decommissioning techniques gave due consideration to the protection of workers.

138. Within GDA Hitachi-GE adopted a systematic approach to its consideration of Human Factors, based on a Human Factors Engineering Specification (Ref.43). By implementing the specification Hitachi-GE aimed to ensure the 'people' component of relevant systems and workspaces was duly considered within the design, allowing the UK ABWR to comply with many Human Factors design standards, meet modern standards and UK regulatory expectations.

139. Early versions of Hitachi-GE's decommissioning submissions contained the following two statements:

- *"A human factors gap analysis has been performed against major decommissioning tasks using the design requirements detailed in the HFE specification to ensure that sufficient space is incorporated into the design to allow major decommissioning tasks to be undertaken unimpeded and without restriction."*
- *"In some instances application of the HF guidance would be grossly disproportionate to the safety requirements for decommissioning and consequently certain areas have been designed with a view to striking a balance between socio-economic factors and operational integrity."*

140. ONR therefore raised RQ-ABWR-1191, which asked Hitachi-GE to supply the referenced HFE gap analysis together with:

- Evidence that the claim made about incorporation of space into the design to assist decommissioning tasks had been achieved, and;
- A justification of the instances where Hitachi-GE believed application of the HFE specification was grossly disproportionate for the purposes of decommissioning.

141. In its response to RQ-ABWR-1191, Hitachi-GE explained that its application of HFE to the operational phase included periodic removal of SSCs for maintenance. Hitachi-GE then asserted that the same space and similar methods would be fit for the purposes of decommissioning and concluded that the layout of the plant did not require any modifications to protect operators. Therefore most of the outputs from its gap analysis were identified as "not a gap". ONR noted:

- Differences between the purpose of decommissioning and the purpose of operational maintenance.
- The possibility that decommissioning will need to take place in different circumstances to operational maintenance (for example, some safety systems may have been removed).
- Decommissioning may require a different scope of work than equipment maintenance (for example, size reduction to allow redundant items to be packaged and exported as wastes).

142. Full development of the UK ABWR maintenance schedule will take place during the site specific phase of design and is subject of operator choices. ONR has therefore raised this residual matter within **Assessment Finding AF-ABWR-D-02** (see Annex 6).

143. Hitachi-GE's analysis identified a gap in relation to de-planting of the equipment that is expected to remain in-situ throughout the whole of the operational phase (e.g. tanks in the Liquid Waste Management System). Hitachi-GE acknowledged that restrictions in space around such equipment will constrain decommissioning activities and considered two design change options; changes to the plant layout, or the removal of cell walls. Hitachi-GE concluded that the cost and difficulty of large-scale re-design (involving the civil structure, piping design and nuclear ventilation) would be grossly disproportionate to the associated benefit for decommissioning, whereas it may be reasonably practicable to engineer certain cell walls so they can be removed safely at the end of the operational phase to allow space and facilitate removal of large plant items.

144. Hitachi-GE therefore identified candidate walls, whose safe removal after the end of station operations could support decommissioning, within GDA. However a full

assessment of the UK ABWR's ability to deliver this potentially important feature was carried forward to the site specific phase of design as an assumption.

145. In the event that a future licensee determines the UK ABWR cannot support the safe removal of the candidate walls at the time required by the decommissioning plan, changes may be necessary to the plant layout and/or the intended decommissioning methods in order to secure ALARP risks. ONR has therefore captured this residual matter within **Assessment Finding AF-ABWR-D-03** (see Annex 6).

146. To test the adequacy of Hitachi-GE's consideration of Radiological Protection in the context of decommissioning, ONR assessed Hitachi-GE's document, 'Dose Consequence Assessment for Major Decommissioning Activities on the UK ABWR'. This report provided a high-level assessment of doses from reactor segmentation and waste packages, to baseline the radiological risks in support of the Decommissioning Safety Assessment.

147. As with other parts of the decommissioning safety case, a fully accurate assessment of doses was not technically feasible within GDA. Despite the inherent uncertainties, the dose assessment contributed to Hitachi-GE judgements on important elements of the UK ABWR design and the viability of intended decommissioning techniques. I therefore raised RQ-ABWR-1122, to ensure that the assumptions, source data and methodology applied in the dose assessment were suitably bounding.

148. In its response to RQ-ABWR-1122 Hitachi-GE provided further justification of its approach, which included:

- Why Hitachi-GE believed it was conservative to assume the source term for the RPV as being entirely ^{60}Co.
- The appropriateness of using a Best Estimate source term.
- The reasons why a dropped $3m^3$ box was considered to be a bounding fault.

149. While ONR identified some areas where Hitachi GE could enhance this analysis (specifically in the practical application of the source term), I judged that these aspects would not significantly alter the report's conclusions. I was therefore broadly content that Hitachi-GE had given an adequate consideration to Radiological Protection in this element of its decommissioning safety case.

150. Following this section of its assessment, I was able to conclude that Hitachi-GE had provided an adequate demonstration that it is technically feasible for the UK ABWR to be safely decommissioned using current technology.

Impacts from Modern Construction Techniques on Decommissioning

151. During steps 2 and 3 of GDA, ONR raised a concern that some of the methods that had been heavily relied on during construction of the J-ABWR (principally modular construction and open-top construction) were not obviously reversible and could have significant dis-benefits for decommissioning if used to build the UK ABWR. To address this concern, ONR sought further evidence from Hitachi-GE on the potential for advanced construction techniques to increase the risks of decommissioning.

152. To address ONR's feedback, Hitachi-GE produced a dedicated Topic Report during Step 4 to consider the matter. When assessing this report, ONR sought strong evidence to substantiate the following arguments that were fundamentally important to the robustness of Hitachi-GE's case for decommissioning:

- *"Unobstructed egress routes without impacting on personnel access and thoroughfares are available for all equipment and items to be removed during decommissioning."*
- *"Sufficient space is provided to operators for undertaking decommissioning tasks."*
- *"To avoid interference with the building structure, export hatches are appropriately sized to accommodate large waste packages e.g. casks, and the design does not foreclose use of alternative waste packaging options."*
- *"The UK ABWR can accommodate removal of walls to facilitate decommissioning."*

153. Hitachi-GE's analysis identified several potential detriments for decommissioning from the use of advanced construction techniques, the most important of which were:

- The use of embedded pipework, which could make it difficult to detect the loss of containment of mobile radioactive materials and wastes, and to remediate any associated contamination.
- Access restrictions, which can increase the complexity of decommissioning and introduce avoidable risks when dealing with large contaminated items in confined spaces with elevated dose-rates.
- The potential for modular construction to restrict the egress routes for removal of large items during decommissioning, giving rise to a need for prolonged size-reduction activities in environments that are not suited to that purpose.

154. Associated with its response to RO-ABWR-54, Hitachi-GE provided evidence that the extent of embedded pipework within the UK ABWR design will be reduced ALARP. However in respect of access restrictions and egress routes for large items, the robustness of Hitachi-GE's case is dependent on design choices that will need to be implemented by a future licensee.

155. In order to mitigate the potential for advanced construction techniques to restrict access and impede egress routes during decommissioning, Hitachi-GE identified candidate walls that could be designed for safe removal at the end of the operational phase. However, full assessment of the UK ABWR's ability to deliver this potentially important feature was carried forward to the site specific phase of design as an assumption, with limited underpinning evidence to demonstrate that it will be practically deliverable.

156. In the event that a future licensee determines the UK ABWR cannot support the inclusion of removable walls, the plant layout and/or decommissioning methods may need to change in order to reduce the associated risks ALARP. Therefore ONR has captured this residual matter within **Assessment Finding AF-ABWR-D-03** (see Annex 6).

Decommissioning Waste Management

157. Decommissioning involves the production of significant volumes and types of both radioactive and conventional wastes. During the decommissioning phase it will also be necessary for a future licensee to safely manage on-site accumulations of the HAW and Spent Fuels that were generated during the operational phase, awaiting disposal to the planned GDF.

158. During Step 4 ONR assessed the relevant Hitachi-GE submissions against a broad range of legislative requirements and regulatory standards. ONR's priorities included:

- Assurance that Hitachi-GE had a comprehensive safety case that identified all decommissioning wastes (gaseous, liquid and solid), including the secondary wastes that may arise as a result of the management of the primary wastes, and considered all steps in waste management from the points of arising through to disposal.

- As an integral part of 'design for decommissioning', the UK ABWR should allow a future licensee to implement the principles of the waste hierarchy, with a preference for waste avoidance or minimisation with disposal as a last resort.

- A demonstration that the design meets the expectations of UK law, policies and other standards applicable to management of decommissioning wastes, including the constraints of anticipated disposal routes.

- A check that Hitachi-GE had applied a precautionary approach to the uncertainties that are inherent to a consideration of decommissioning wastes during the early stages of design.

- To ensure Hitachi-GE's proposals recognised established good practices in the management of decommissioning wastes (e.g. segregation based on UK waste categorisations, appropriate use of decontamination, storage of conditioned wastes in a passive safe form).

159. In addition to assessing PCSR Chapter 31 and the dedicated Topic Report on Management of Decommissioning Wastes, this section of ONR's assessment was directly informed by reviews of PCSR Chapter 18, the Radioactive Waste Management Arrangements document (RWMA), Integrated Waste Strategy (IWS) and RWM Ltd's report on disposability of the anticipated UK ABWR HAW.

160. I have also considered the integration of Hitachi-GE's proposals for decommissioning wastes with the systems that will be in place during the operational phase (i.e. the Liquid Waste Management System, Solid Waste Management System, nuclear ventilation and Off Gas System).

161. Throughout all the above submissions Hitachi-GE demonstrated comprehensive awareness and understanding of the relevant UK waste categorisations, disposal criteria and UK policies including the waste hierarchy.

162. Hitachi-GE's submissions for the management of decommissioning wastes contained a considerable amount of information on design features whose performance throughout the operational phase will contribute to waste avoidance and minimisation (e.g. materials selection, contamination control, fuel design and control of coolant chemistry). In broad terms this approach met ONR's expectations in relation to implementation of the waste hierarchy to decommissioning wastes. In-depth assessment of all the component parts of the UK ABWR case had to take into account the impacts for waste management in addition to other safety criteria and therefore involved a broad range of other ONR technical disciplines within GDA, such as Fuel and Core, Reactor Chemistry and Radiological Protection.

163. Hitachi-GE presented the major sources of wastes expected to arise in each of the seven phases of the decommissioning plan, together with the waste types, expected categorisations, estimated volumes, anticipated disposal routes and descriptions of the intended waste treatment routes. However the regulators' assessment found several areas in need of further clarification, which were captured in RQ-ABWR-1151. The main areas for improvement were:

- Hitachi-GE initially stated that decommissioning was not expected to give rise to any 'borderline wastes' (i.e. wastes with a radioactive content close to a transition

point between different UK waste categorisations). Hitachi-GE was asked to clarify the basis of this statement, due to potential 'cliff-edge' effects if the assumed categorisation of significant waste-streams proved to be incorrect.

In response Hitachi-GE explained that its initial decommissioning waste inventory was derived from the 'Best Estimate' Decommissioning End User Source Term (EUST), supplemented by an assessed effectiveness of anticipated decontamination methods. The Best Estimate EUST represented the likely activity levels in the UK ABWR systems from normal reactor operations.

To address the regulators' concern and consider the potential impact of design uncertainty, Hitachi-GE then applied its 'Design Basis' Decommissioning EUST to determine if application of the Design Basis values would change the categorisation of any decommissioning waste streams. The Design Basis EUST represented an upper bound estimate of activity levels in the UK ABWR systems, derived from normal operations combined with foreseeable events.

Hitachi-GE found that application of the Design Basis EUST caused the following decommissioning wastes to change in categorisation at the time decommissioning is expected to be carried out:

- Reactor Internals ILW ⟹ HLW
- Reactor Internals LLW ⟹ ILW
- Reactor Pressure Vessel segments LLW ⟹ ILW
- Miscellaneous contaminated items LLW ⟹ ILW (pipes, vessels and pond furniture)
- Water treatment resins LLW ⟹ ILW
- Water treatment filters LLW ⟹ ILW

Hitachi-GE subsequently updated its inventory data, to show instances where Design Basis EUST values would cause wastes to have a higher categorisation, or an increased waste quantity. Hitachi-GE then updated other submissions to demonstrate that the UK ABWR design incorporated sufficient flexibility for the future operator to manage all the wastes that may be produced if activity levels reach the Design Basis range. ONR was content that this amended approach was adequate for the purposes of GDA.

- The regulators sought assurance that Hitachi-GE's expectations for decommissioning wastes were not based on overly optimistic assumptions on the likely effectiveness of decontamination processes. Hitachi-GE developed a Decommissioning Decontamination Strategy document, which addressed my concern and recognised:
  - Particular considerations for in-situ decontamination and ex-situ decontamination
  - Typical potential benefits from decontamination (e.g. reduced categorisation of waste items and reduced dose rates in working areas)
  - Typical potential detriments from decontamination (e.g. increased worker doses from manual methods and creation of secondary wastes)
  - The need for the principles of ALARP and BAT to be applied in reaching a balanced decision over which decontamination options should be deployed

164. In accordance with the regulators' expectations for GDA, Hitachi-GE sought an assessment from RWM Ltd (on behalf of NDA) of the disposability of the HAW and spent fuels expected to arise from operation and decommissioning of the UK ABWR. RWM Ltd reported that: *"ILW and spent fuel from the operation and decommissioning of a UK ABWR should be compatible with plans for transport and subsequent disposal of higher activity wastes and spent fuel… and the assessment process has not*

identified any significant issues that challenge fundamental disposability of the wastes and spent fuel expected to be generated from operation of such a reactor".

165. In the course of its assessment, RWM Ltd identified 27 areas for further consideration (23 related to management of ILW and 4 related to spent fuel), which was consistent with expectations at this stage of the design due to the preliminary nature of Hitachi-GE's proposals and the relatively high-level assessments performed. Some of the areas identified by RWM Ltd were relevant to Hitachi-GE's proposals for the management of decommissioning wastes, including:

- The optimum timing for disposal of ILW - for some waste streams, RWM Ltd suggested that a period of decay storage may be an appropriate strategy to enable the UK transport limits and operational limits at the GDF to be complied with.
- Packing arrangements for RPV decommissioning wastes – RWM Ltd suggested the RPV wastes should be packaged in $3m^3$ boxes and transported in standard waste transport containers in preference to Hitachi-GE's initial proposal to use 4m boxes.
- RWM Ltd suggested that Hitachi-GE's assumed packing density for redundant control rods within $3m^3$ boxes may be overly optimistic.

166. RWM Ltd made its findings in expectation that further development of the inventories, packaging plans and performance of the packaged wastes will be undertaken by either the requesting party or future licensee. Within its response to RWM Ltd, Hitachi-GE noted that the absence of any major issues suggested the further work would be best addressed at the site specific phase of design.

167. Full resolution of RWM Ltd's advice therefore requires the input of a future licensee. Potential also exists for a future licensee to make choices on the UK ABWR detailed design and operations that may have an impact the disposability of decommissioning wastes. If decommissioning were to give rise to non-disposable HAW it would not result in a non-compliance with UK law, but may impact on the ability of a future licensee to delicense the site. Therefore this residual matter has been raised as **Minor Shortfall MS-ABWR-D-01** (see Annex 7).

168. As a result of this section of its assessment, I concluded that Hitachi-GE had provided adequate evidence that all the radioactive wastes expected to be generated during decommissioning of the UK ABWR can be appropriately managed and should be disposable at current or planned facilities within the UK.

Integration of Decommissioning with other parts of the UK ABWR Safety Case

169. Throughout Step 4 ONR sampled Hitachi-GE's submissions across a wide range of technical areas, to ensure adequate and consistent coverage of the decommissioning topic across all relevant parts of the safety case.

170. RQ-ABWR-1135 was raised to address several inconsistencies between submissions made on the topics of decommissioning and Reactor Chemistry, concerning; surface treatment methods; the intended scope of chemical decontamination, and application of On Line Noble Metal Chemical Addition. In response to the RQ, Hitachi-GE provided further clarification and made appropriate changes to its submissions.

171. The need for Hitachi-GE to strengthen its systematic approach to the conventional safety aspects of decommissioning was a relevant consideration within RQ-ABWR-1184, through which ONR sought assurance that Hitachi-GE properly recognised its statutory responsibilities as a designer in the terms of Regulation 9 of the Construction (Design and Management) Regulations 2015. ONR's assessment of Hitachi-GE's response to RQ-ABWR-1184 is reported in Ref.13.

172. Numerous Mechanical Engineering systems will be expected to make significant contributions to the delivery of decommissioning, the most important of which are described below:

- Hitachi-GE confirmed that the requirements for nuclear cranes during decommissioning were bounded in all instances by the demands of the operational phase, therefore decommissioning would not create any additional requirements other than the need for cranes to have a sufficiently long service life to support decommissioning. However ONR noted that the quoted design life of some relevant systems did not apparently match the requirements of the decommissioning plan, for example the Liquid Waste Management System.

- PCSR Chapter 16 (Auxiliary Systems) identified a requirement for the Heating Ventilation and Air Conditioning (HVAC) system to have continued functionality into the decommissioning phase. Hitachi-GE's stated expectation was that the HVAC systems designed for plant operation will be broadly acceptable for decommissioning activities and therefore significant changes to the system specification or plant layout were not anticipated. However ONR found that no claims had been made on the HVAC system to define its expected role during decommissioning. ONR additionally noted the potential for typical decommissioning tasks (such as scabbling, decontamination and hot cutting) to give rise to more onerous demands for ventilation than the circumstances during normal operations, which may require new or modular HVAC systems to be made available. I have therefore captured this residual matter within **Assessment Finding AF-ABWR-D-01** (see Annex 6).

173. RQ-ABWR-1159 was raised to ensure that Hitachi-GE fully understood UK expectations in relation to knowledge management and the need to capture all relevant information for the purposes of future decommissioning. Knowledge management is an important concern in relation to decommissioning, given the need to maintain an accurate understanding of the 'as built' plant over long durations, including any significant design changes, modifications and any departures from the expected plant conditions.

174. Resolution of this matter will require a future licensee to put in place adequate arrangements for the retention of knowledge relating to decommissioning, therefore I have captured this residual matter in **Assessment Finding AF-ABWR-D-04** (see Annex 6).

4.3 Regulatory Issues

175. Regulatory Issues (RIs) in the context of GDA were matters that ONR judged to represent a 'significant safety shortfall' in the safety case or design and are the most serious regulatory concerns. Requesting Parties are required to address all RIs before a DAC can be issued.

176. No RIs were raised directly against Hitachi-GE's decommissioning submissions during Step 4. However decommissioning was a relevant consideration to RI-ABWR-0001, which required Hitachi-GE to provide an adequate definition and justification for the UK ABWR radioactive source terms and was raised by ONR's Reactor Chemistry discipline in the earlier steps of the GDA.

177. To resolve RI-ABWR-0001 Hitachi-GE presented a basis, methodology and calculated values for the radioactive source term in a suite of documents arranged in a tiered structure including a high-level Strategy Report, Source Term Manual, Source Term value data sets and other supporting reports. The Strategy Report described how the

data from the source term was applied to the safety and environmental cases during GDA and how the suite of documents will be updated throughout the plant's lifecycle.

178. With provision of this new evidence Hitachi-GE successfully addressed the shortfalls identified in RI-ABWR-001, which allowed ONR's Reactor Chemistry Specialism to close the RI prior to the end of Step 4.

4.4 Regulatory Observations

179. Regulatory Observations (ROs) were raised within GDA when ONR identified a 'potential regulatory shortfall', the resolution of which required action and new work by the Requesting Party. ROs can have several associated actions.

180. No ROs were raised directly against Hitachi-GE's decommissioning submissions during Step 4. However decommissioning was a relevant consideration to ROs that were raised by other assessment disciplines (Annex 5). A selection of these are summarised below.

- **RO-ABWR-0006** set out the regulators' expectations regarding operational states of the UK ABWR against which Hitachi-GE was asked to demonstrate that source terms had been reduced SFAIRP, including in the event of design basis and severe accidents.
- **RO-ABWR-0035** required a justification for the materials selected for UK ABWR, including consideration of any effects for decommissioning such as the levels of activation and contamination that will be present at the end of the operational phase.
- **RO-ABWR-0036** required a demonstration that the risks associated with management of radioactive wastes will be reduced SFAIRP.
- **RO-ABWR-0045** required a demonstration of adequate knowledge of all BWR and ABWR operational experience across the world and to consider operational experience to reduce risks So Far As is Reasonably Practicable (SFAIRP).
- **RO-ABWR-0054** addressed shortfalls against UK expectations within Hitachi-GE's design approach for Chemical Engineering and had particular implications for the UK ABWR liquid waste management system. The UK ABWR design was rigorously tested during GDA to reduce its reliance on embedded pipework, floor drains and equipment drains, partly because the amount of embedded pipework in Hitachi-GE's original proposal was likely to present a significant challenge to achievement of the NIA65 'no danger' criterion and final delicensing of the site.
- **RO-ABWR-0064** concerned design features to enable adequate control of radioactive contamination across the full lifetime of UK ABWR.

181. All of the above ROs were closed by ONR's relevant disciplines within the planned timescales of the GDA.

4.5 Assessment Findings

182. During this assessment some residual matters were identified for a future licensee to take forward in its site-specific safety submissions.

183. These matters do not undermine ONR's confidence in the generic safety case and are primarily concerned with the provision of site specific evidence, which is expected to become available as the project progresses through the detailed design, construction and commissioning stages.

184. In accordance with the Guidance to Requesting Parties, such residual matters were recorded as Assessment Findings if one or more of the following applied:

- Resolution of the matter required site-specific information.
- Resolution of the matter depended on licensee design choices.
- The matter related to other licensee-specific features / aspects / choices associated with future operational philosophy.
- Resolution of the matter required a greater level of detail on the design than can reasonably be expected in GDA.
- Resolution of the matter was not practicable until the plant enters the phases of construction or commissioning.

185. Assessment Findings must be addressed by any future licensee and the progress of this will be formally monitored by ONR.

186. The full list of Assessment Findings raised during this assessment can be found in Annex 6.

4.6 Minor Shortfalls

187. During this assessment one residual matter was identified as a minor shortfall in the safety case, as it was not considered to be serious enough to require specific action to be taken by the future licensee in response to ONR. This minor shortfall relates to further work on the assessment of disposability of decommissioning wastes that has already been identified by RWM Ltd and Hitachi-GE and would not impede the UK ABWR's ability to comply with UK law.

188. In accordance with the Guidance to GDA Requesting Parties, a residual matter is 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.

189. The full narrative of the Minor Shortfall can be found in Annex 7.

5 CONCLUSIONS

190. This report presents the findings of ONR's Step 4 assessment of Hitachi-GE's UK ABWR design in the topic area of decommissioning.

191. Four assessment findings and one minor shortfall were identified; these are for a future licensee to consider and take forward in its site-specific safety submissions. These matters do not undermine ONR's confidence in the generic safety submission.

192. To conclude, I am broadly satisfied with the claims, arguments and evidence laid down within the PCSR and supporting documentation for the decommissioning topic. Therefore from the perspective of decommissioning I have no objection to Hitachi-GE's UK ABWR design being awarded a Design Acceptance Confirmation.

Key Findings from the Step 4 Assessment

193. My key assessment conclusions are:

- Hitachi-GE has developed a decommissioning strategy and plan for the UK ABWR, based on prompt dismantling after the reactor's 60-year operating life, which aligns with UK law, is compatible with UK Government policy and meets UK regulatory expectations.

- Hitachi-GE has provided adequate evidence that it is technically feasible for the UK ABWR design to be safely decommissioned using current technology.

- Hitachi-GE's intended end-point for decommissioning of the UK ABWR is for the site to be delicensed and Hitachi-GE has taken steps to ensure that the design is compatible with achievement of that objective. This is consistent with UK law and regulatory expectations.

- Hitachi-GE has provided adequate evidence that all the radioactive wastes expected to be generated during decommissioning of the UK ABWR can be appropriately managed and should be disposable at current or planned facilities within the UK.

- Hitachi-GE has shown that the UK ABWR complies with the principle of 'design for decommissioning', wherein the design takes account of the need to achieve future decommissioning and ensure the associated risks are reduced SFAIRP.

- Hitachi-GE has challenged its reference design and operating philosophy for the UK ABWR to identify potential improvements that can reduce the risks of future decommissioning SFAIRP.

- Hitachi-GE's proposals for decommissioning are based on a precautionary approach to uncertainty, such that the technical viability of the intended decommissioning strategy and techniques do not depend on optimistic assumptions on how the UK ABWR will perform in practice.

6 REFERENCES

1. Summary Report of the Step 3 Generic Design Assessment (GDA) of Hitachi-GE Nuclear Energy's UK Advanced Boiling Water Reactor (UK ABWR), Office for Nuclear Regulation, October 2015 (http://www.onr.org.uk/new-reactors/UK ABWR/reports/step3/UK ABWR-step-3-summary-report.pdf)
2. New Nuclear Reactors: Generic Design Assessment, Guidance to Requesting Parties, Office for Nuclear Regulation, ONR-GDA-GD-001, Revision 3, September 2016, (http://www.onr.org.uk/new-reactors/ngn03.pdf)
3. Safety Assessment Principles for Nuclear Facilities, 2014 Edition, Revision 0, Office for Nuclear Regulation, November 2014, (http://www.onr.org.uk/saps/saps2014.pdf)
4. Generic Design Assessment of Hitachi-GE's UK Advanced Boiling Water Reactor (UK ABWR), Step 4 Assessment Plan for Management of Radioactive Wastes, Management of Spent Fuel and Decommissioning, Office for Nuclear Regulation, ONR-GDA-AP-15-011, Revision 0, November 2015.
5. Decommissioning of Facilities, IAEA General Safety Requirements Part 6, No. GSR Part 6 http://www-pub.iaea.org/MTCD/publications/PDF/Pub1652web-83896570.pdf
6. Guidance on Mechanics of Assessment, Office for Nuclear Regulation, Version 1.0, 31 May 2013.
7. Office for Nuclear Regulation, GDA of the UK ABWR, Step 4 Assessment Report, Management of Radioactive Wastes, ONR-NR-AR-17-025.
8. Office for Nuclear Regulation, GDA of the UK ABWR, Step 4 Assessment Report, Spent Fuel Interim Storage, ONR-NR-AR-17-030.
9. Office for Nuclear Regulation, GDA of the UK ABWR, Step 4 Assessment Report, Reactor Chemistry, ONR-NR-AR-17-020.
10. Office for Nuclear Regulation, GDA of the UK ABWR, Step 4 Assessment Report, Civil Engineering, ONR-NR-AR-17-013.
11. Office for Nuclear Regulation, GDA of the UK ABWR, Step 4 Assessment Report, Human Factors, ONR-NR-AR-17-023.
12. Office for Nuclear Regulation, GDA of the UK ABWR, Step 4 Assessment Report, Radiological Protection, ONR-NR-AR-17-021.
13. Office for Nuclear Regulation, GDA of the UK ABWR, Step 4 Assessment Report, Conventional Health and Safety, ONR-NR-AR-17-028.
14. Office for Nuclear Regulation, GDA of the UK ABWR, Step 4 Assessment Report, Fault Studies, ONR-NR-AR-17-016.
15. Office for Nuclear Regulation, GDA of the UK ABWR, Step 4 Assessment Report, Mechanical Engineering, ONR-NR-AR-17-022.
16. Office for Nuclear Regulation, GDA of the UK ABWR, Step 4 Assessment Report, Management for Safety and Quality Assurance, ONR-NR-AR-17-024.
17. Enforcement Policy Statement, Office for Nuclear Regulation, ONR-ENF-POL-001, Revision 1, 1 April 2014 (http://www.onr.org.uk/documents/2014/enforcement-policy-statement.pdf)
18. The Energy Act 2008, Funded Decommissioning Programme Guidance for New Nuclear Power Stations, December 2011. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/70214/guidance-funded-decommissioning-programme-consult.pdf
19. Hitachi-GE Nuclear Energy Generic PCSR Chapter 31: Decommissioning, Revision C, GA91-9101-0101-31000, DCE-GD-0007, 31 August 2017.
20. Hitachi-GE Nuclear Energy Topic Report: Decommissioning Plan, Revision 3, GA91-9201-0001-00176, DCE-GD-0066, 27 July 2017.
21. Hitachi-GE Nuclear Energy Topic Report: Design for Decommissioning, Revision 3, GA91-9201-0001-00172, DCE-GD-0065, 27 June 2017.

22. Hitachi-GE Nuclear Energy Topic Report: Decommissioning Techniques, Revision 2, GA91-9201-0001-00174, DCE-GD-0067, 28 June 2017.

23. Hitachi-GE Nuclear Energy Topic Report: Decommissioning Strategy, Revision 3, GA91-9201-0001-00175, DCE-GD-0064, 28 July 2017.

24. Hitachi-GE Nuclear Energy Topic Report: Impact of Construction Techniques on Decommissioning, Revision 1, GA91-9201-0001-00178, DCE-GD-0068, 30 March 2017.

25. Hitachi-GE Nuclear Energy Topic Report: Decommissioning Waste Management, Revision 6, GA91-9201-0001-00173, DCE-GD-0069, 28 July 2017.

26. Hitachi-GE Nuclear Energy Topic Report: Decommissioning Safety Assessment, Revision 2, GA91-9201-0001-00177, DCE-GD-0070, 27 June 2017.

27. Hitachi-GE Nuclear Energy HAZOP Report - Activities within the Decommissioning Phase on UK ABWR, Revision 1, GA91-9201-0003-01346, DCE-GD-0081, 30 March 2017.

28. Hitachi-GE Nuclear Energy ALARP Review of Potential Risk Reduction Measures on UK ABWR Decommissioning, Revision 1, GA91-9201-0003-01447, DCE-GD-0084, 30 March 2017.

29. Hitachi-GE Nuclear Energy Dose Rate and Radiological Consequence Assessment for Major Decommissioning Activities, Revision 1, GA91-9201-0003-01347, DCE-GD-0082, 30 March 2017.

30. Hitachi-GE Nuclear Energy Supporting Document on Decommissioning: Decontamination Strategy, GA91-9201-0003-01325, DCE-GD-0080, Rev. 0, November 2016.

31. Hitachi-GE Nuclear Energy Response to RWM Assessment Report on UK ABWR Waste and Spent Fuel Disposability, GA91-9201-0003-01150, XE-GD-0546, Revision 0, 28 September 2016.

32. Hitachi-GE Nuclear Energy Integrated Waste Strategy, GA91-9201-0003-00425, WE-GD-0050, Revision 3, July 2017.

33. Hitachi-GE Nuclear Energy Topic Report: CDM Compliance (Response to RQ-ABWR-1184), Revision 1, GA91-9201-0001-00253, XE-GD-0706, 31 May 2017.

34. Hitachi-GE Nuclear Energy HAZOP Report Supporting Document: Dose Consequence Assessment for Major Decommissioning Activities on UK ABWR, Revision 1, GA91-9201-0003-01347, DCE-GD-0082, 30 March 2017.

35. Hitachi-GE Nuclear Energy Contamination Control Philosophy, Revision 2, Section 9, GA91-9201-0003-01231, HE-GD-5192, 5 August 2016.

36. Hitachi-GE Nuclear Energy OPEX Report for UK ABWR, Revision 5, GA91-9201-0003-00698, XE-GD-0419, 25 July 2017.

37. Hitachi-GE Nuclear Energy Main Faults and Fault Groupings – Activities within the decommissioning phase on the UK ABWR, Revision 1, GA91-9201-0003-01348, DCE-GD-0083, 30 March 2017.

38. Hitachi-GE Nuclear Energy GDA ALARP Methodology, Revision 1, GA10-0511-0004-00001, XD-GD-0037, 2 December 2015.

39. Radioactive Waste Management Ltd, Generic Design Assessment: Disposability Assessment for Wastes and Spent Fuel arising from Operation of the UK ABWR Part 1: Main Report, Issue 1, September 2015.

40. Office for Nuclear Regulation, How2 Business Management System document NS-PER-GD-014, Revision 6, November 2016, TRIM Record 2016/448079.

41. Technical Baseline and Underpinning Research and Development Requirements, Nuclear Decommissioning Authority, Doc No EGG10, Revision 6, November 2014. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/456127/EGG10_Technical_Baseline_and_Underpinning_Research_and_Development_Requirements_Rev6.pdf

42. Reducing Risks, Protecting People; HSE Books 2001.

43. Hitachi-GE Nuclear Energy Human Factors Engineering Specification, GA91-9201-0001-00037, HFD-GD-0001, Revision D, 18 January 2017.

Annex 1
Safety Assessment Principles

SAP No	SAP Title	Description
MS.2	Leadership and Management for Safety	Knowledge should be captured and communicated within the organisation in a systematic, appropriate and reliable manner to all those who need to make safety decisions. Documents and records relevant to safety should include those for modifications and decommissioning.
SC.1	Safety Case Production Process	The process for producing safety cases should be designed and operated commensurate with the hazard, using concepts applied to high reliability engineered systems.
SC.2	Safety case process outputs	The process for producing safety cases should take into account the needs of those who will use the safety case to ensure safe operations. It is essential that the safety case documentation is clear and logically structured so that the information is easily accessible to those who need to use it. This includes designers, operations and maintenance staff, technical personnel and managers who are accountable for safety.
SC.3	Lifecycle aspects	Control of hazards should be demonstrated in a safety case before any associated risks materially exist. The safety case for each stage should take account of future lifecycle stages, i.e. it should build on the safety case for previous stages and show that the safety intent for subsequent stages will be achieved. Any constraints that apply in subsequent stages should be detailed in the safety case in which they are identified. The safety case for decommissioning should have been considered in all previous lifecycle stages. In the case of early, unplanned permanent shutdown of a facility, the safety case should be revised to address any safety implications arising from the early shutdown and to identify any changes to the strategy and timescales for decommissioning.
SC.4	Safety case characteristics	A safety case should: (a) explicitly set out the argument for why risks are ALARP; and (b) link the information necessary to show that risks are ALARP, and what will be needed to ensure that this can be maintained over the period for which the safety case is valid; (c) support claims and arguments with appropriate evidence, and with experiment and/or analysis that validates performance assumptions; (d) accurately and realistically reflect the proposed activity, facility and its structures, systems and components; (e) identify all the limits and conditions necessary in the interests of safety (operating rules); and (f) identify any other requirements necessary to meet or maintain the safety case such as surveillance, maintenance and inspection.
SC.5	Optimism, uncertainty and conservatism	The safety case should present a balanced view of the level of knowledge and understanding, and of the resultant risks. It should provide a proportionate justification that includes appropriate conservatism but without undue pessimism. Otherwise, it

		can mislead those who need to use the safety case to take decisions on risks and on managing safety. An unbalanced case will also fail to identify areas where more work might be needed, either to support the current conclusions or to provide a valid basis for any subsequent work if the safety case needs to be revised (e.g. due to a proposed plant modification or a change to the operating regime or procedures). This principle encompasses optimism and uncertainties in the design of a facility (e.g. material properties, defects and dynamic behaviour) and in the basis of the safety case (e.g. analytical methods and codes, underlying assumptions, data, margins and factors of safety). Areas of uncertainty should be offset by a precautionary approach.
SC.6	Safety case content and implementation	The safety case for a facility or site should identify the important aspects of operation and management required for maintaining safety and how these will be implemented.
DC.1	Decommissioning: Design and Operation	Decommissioning and waste retrieval should be taken into account during the planning, design, construction and operational stages of a new facility.
DC.2	Decommissioning Strategies	A decommissioning strategy should be prepared and maintained for each site and should be integrated with other relevant strategies.
DC.3	Timing of Decommissioning	The safety case should justify the continuing safety of the facility for the period prior to its decommissioning. Where adequate levels of safety cannot be demonstrated, prompt decommissioning should be carried out and, where necessary, prompt remedial and operational measures should be implemented to reduce the risk.
DC.4	Planning for Decommissioning	Account needs to be taken, throughout the lifecycle of a facility, of its future decommissioning and to manage its wastes. This requires that a strategy and a plan be prepared for each facility setting out how the facility will be safely decommissioned.
DC.5	Passive Safety	Facilities should be made passively safe before entering a care and maintenance phase.
DC.6	Records for Decommissioning	Documents should be identified, prepared, updated and retained so that they will be available when needed for decommissioning purposes.
DC.7	Decommissioning Organisation	Organisational arrangements should be established and maintained to ensure safe and effective decommissioning.
DC.9	Decommissioning Safety Case	A safety case should be provided to demonstrate the safety of the decommissioning plan and its associated decommissioning activities and kept up to date as the work progresses.
ECE.26	Engineering Principles - Provision for Decommissioning	Special consideration should be given at the design stage to the incorporation of features to facilitate radioactive waste management and the future decommissioning and dismantling of the facility.

ELO.1	Layout and Access	The layout should make provision for construction, assembly, installation, erection, decommissioning, maintenance and demolition.
EHF.1	Human Factors Integration with Design, Assessment and Management	A systematic approach to integrating human factors within the design, assessment and management of systems and processes should be applied throughout the facility's lifecycle.
FA.2	Identification of initiating faults	The process for identifying faults should be systematic, auditable and comprehensive, and should include planned operating modes and configurations, shutdown states, decommissioning operations, and any other activities which could present a radiological risk.
FA.3	Fault Sequences	Fault sequences should be developed from the initiating faults and their potential consequences analysed. Following the end of operations, a new fault analysis is likely to be needed to cover the decommissioning phase.
RL.1	Land Quality Management	A strategy should be produced for the control and remediation of any radioactively contaminated land on the site.
EMT.1	Engineering principles: maintenance, inspection and testing	Safety requirements for in-service testing, inspection and other maintenance procedures and frequencies should be identified in the safety case.
ENM.1	Engineering principles: control of nuclear matter	Strategies should be made and implemented for the management of nuclear matter.
NT.2	Numerical targets and legal limits – Time at Risk	There should be sufficient control of radiological hazards at all times.
RP.7	Radiation Protection	The dutyholder should establish a hierarchy of control measures to optimise protection in accordance with IRR99.
RP.5	Decontamination	Suitable and sufficient arrangements for decontaminating people, the facility, its plant and equipment should be provided.
RP.6	Shielding	Where shielding has been identified as a means of restricting dose, it should be effective under all normal operation and fault conditions where it provides this safety function. The Safety case should take into account any post-operational period prior to final decommissioning.
RW.1	Radioactive Waste Management	The management of radioactive waste is a function potentially spanning all the stages of the lifecycle of a facility. A strategy should be produced and implemented for the management of radioactive waste on a site which should be integrated with the decommissioning strategy.
RW.2	Generation of Radioactive Waste	The safety case should describe approaches to decommissioning that will ensure waste minimisation and include a demonstration that the rate of production of radioactive waste has been minimised.
RW.3	Accumulation of Radioactive Waste	The total quantity of radioactive waste accumulated on site at any time should be

		minimised so far as is reasonably practicable.
RW.5	Storage of radioactive waste and passive safety	Radioactive waste should be stored in accordance with good engineering practice and in a passively safe condition.
RW.7	Making and keeping records	Information that might be needed for the current and future safe management of radioactive waste should be recorded and preserved.

Annex 2
Technical Assessment Guides

TAG Ref	TAG Title
NS-TAST-GD-005	Guidance on the Demonstration of ALARP (As Low As Reasonably Practicable)
NS-TAST-GD-021	Containment: Chemical Plants
NS-TAST-GD-024	Management of Radioactive Materials and Radioactive Waste on Nuclear Licensed Sites
NS-TAST-GD-026	Decommissioning
NS-INSP-GD-034	LC34: Leakage and Escape of Radioactive Material and Radioactive Waste
NS-TAST-GD-051	The purpose, scope, and content of safety cases
NS-TAST-GD-057	Design Safety Assurance
NS-TAST-GD-081	Safety aspects specific to storage of spent nuclear fuel
NS-TAST-GD-088	Chemistry of Operating Civil Nuclear Reactors
NS-TAST-GD-094	Categorisation of Safety Functions and Classification of Structures and Components
NS-TAST-GD-098	Asset Management

Annex 3
National and International Standards and Guidance

National and International Standards and Guidance
Safety of Nuclear Power Plants: Design. Safety Requirements, IAEA Safety Standards Series No. NS-R-1. IAEA. Vienna. 2000. www.iaea.org.
Methods for the Minimization of Radioactive Waste from Decontamination and Decommissioning of Nuclear Facilities, Technical Report Series 401.
Safety of Nuclear Fuel Facilities, IAEA Safety Standards Series No. NS-R-5.
Decommissioning of Facilities, IAEA General Safety Requirements Part 6, No. GSR Part 6
Decommissioning of Nuclear Fuel Cycle Facilities, IAEA Safety Standards Series No. WS-G-2.4.
Decommissioning of Facilities Using Radioactive Material, IAEA Safety Standards Series No. WS-R-5.
Design Lessons Drawn from the Decommissioning of Nuclear Facilities, IAEA-TECDOC-1657.
Decommissioning of Nuclear Power Plants and Research Reactors, IAEA Safety Standards Series No.WS-G-2.1.
Decommissioning of Medical, Industrial and Research Facilities, IAEA Safety Standards Series No. WS-G-2.2.
Fundamental Safety Principles, IAEA Safety Standards, Safety Fundamentals SF-1.
WENRA Statement on Safety Objectives for New Nuclear Power Plants, November 2010.
WENRA Reactor Reference Safety Levels, September 2014.
WENRA Waste and Spent Fuel Storage Safety Reference Levels, Report of Working Group on Waste and Decommissioning (WGWD), Version 2.2, April 2014, http://www.wenra.org/media/filer_public/2014/05/08/wgwd_storage_report_final.pdf
Joint Guidance, The Management of Higher Activity Radioactive Waste on Nuclear Licensed Sites, February 2015 Revision 2.
Industry Guidance - Interim Storage of Higher Activity Waste Package – Integrated Approach, November 2012.
Approved Code of Practice, Managing Health and Safety in Construction – Construction (Design and Management) Regulations 2015.
Approved Codes of Practice, Working with Ionising Radiation – Ionising Radiations Regulations 1999.
Reducing Risks, Protecting People; HSE Books 2001.
HSE Criterion for Delicensing Nuclear Sites, May 2005, http://www.onr.org.uk/delicensing.pdf

Delicensing Guidance, Guidance to Inspectors on the Interpretation and Implementation of the HSE Policy Criterion of No Danger for the Delicensing of Nuclear Sites, 13th August 2008, http://www.onr.org.uk/delicenceguide.pdf
Guidance on the Nuclear Reactors (Environmental Impact Assessment for Decommissioning) Regulations, Health and Safety Executive, Nuclear Directorate, http://www.onr.org.uk/eiadrguidance.pdf

Annex 4
Decommissioning Regulatory Queries

RQ Ref	RQ Title	Description	Report Section Reference
RQ-ABWR-0646	Organisation in Decommissioning	To emphasise the importance of key ONR expectations for the consideration of decommissioning within GDA.	4.2
RQ-ABWR-0825	Optimisation of Future Commitments	Highlighted ONR's expectation for future decommissioning activities to be enabled by the design and sought assurance Hitachi-GE's deferral of design decisions to the future operator was being managed correctly, with a proportionate level of optimisation secured within GDA.	4.2
RQ-ABWR-0826	Decommissioning of Large Items	A request for Hitachi-GE to demonstrate that its proposals included a systematic identification of all large, heavy and contaminated items that will need to be removed from the plant during decommissioning.	4.2
RQ-ABWR-0827	Decommissioning and the requirements of RO-ABWR-0057	To ensure that Hitachi-GE's arrangements for moving the safety case to an operating regime included due consideration of decommissioning.	4.2
RQ-ABWR-0833	Optimisation in Decommissioning	A request for further evidence to demonstrate the UK ABWR design and operating philosophies had been systematically and comprehensively challenged, to identify all reasonably practicable measures to reduce the challenges and risks of future decommissioning ALARP.	4.2
RQ-ABWR-1023	Assumptions in GA91-9201-0001-00174, Topic Report on Decommissioning: Decommissioning Techniques	A request for further evidence to demonstrate that Hitachi-GE's choice of decommissioning techniques was based on a precautionary approach to uncertainty.	
RQ-ABWR-1122	Demonstration that the Decommissioning Dose Assessment is based on a Precautionary Approach to Uncertainty	A request for further evidence to demonstrate that the basis of Hitachi-GE's estimation of the doses expected to arise from key decommissioning activities was suitably bounding.	4.2
RQ-ABWR-1125	Civil Engineering Queries on Impacts of Construction Techniques on Decommissioning	A consideration of how the construction techniques adopted for the UK ABWR may influence; future decontamination of the civil structures and plant supports; potential delayed deconstruction that may require elements of the civil structures to remain in place for extended periods and so require additional durability provisions to ensure continued structural stability.	4.2
RQ-ABWR-1126	Demonstration of Relevant Good Practice in Decommissioning	To review global decommissioning experience and identify worthwhile lessons learned that could inform design improvements to enhance the safety of decommissioning the UK ABWR.	4.2
RQ-ABWR-1135	Inconsistencies between submissions	To resolve apparent inconsistencies between submissions Hitachi-GE made on the	4.2

	for Decommissioning and Reactor Chemistry	topics of Decommissioning and Reactor Chemistry.	
RQ-ABWR-1151	Borderline Wastes and Decontamination Techniques in Decommissioning	To clarify the potential for decommissioning of the UK ABWR to generate wastes with a radioactive inventory near to a waste classification boundary and consider any associated sensitivities for the design.	4.2
RQ-ABWR-1158	Need for a precautionary approach to the use of assumptions in decommissioning (follow up to RQ-ABWR-1023)	To ensure Hitachi-GE demonstrated a precautionary approach to its use of decommissioning assumptions, to protect the capability of the future site operator to decommission the UK ABWR with risks reduced ALARP.	4.2
RQ-ABWR-1159	Records Management for Decommissioning	To demonstrate that Hitachi-GE fully understood expectations for Records Management to capture all relevant information for decommissioning.	4.2
RQ-ABWR-1173	Potential Future Widening of the DSP/SFP Gates for the Purposes of Decommissioning	Widening of the DSP and SFP access ways has potential to reduce the risks and technical difficulty of decommissioning ALARP. Hitachi-GE was therefore asked to explain the issues associated with widening the access ways between the reactor well pool, Spent Fuel Pond (SFP) and Drier Separator Pond (DSP) to allow easier passage of activated and contaminated items, including size reduced sections of the Reactor Pressure Vessel (RPV), during decommissioning.	4.2
RQ-ABWR-1177	Potential to segment the Reactor Pressure Vessel (RPV) underwater during Decommissioning	Segmentation of the RPV is a major decommissioning task, with the potential to give a significantly elevated dose to operators if inadequately conceived or executed. ONR understood that a combination of measures to make the reactor well pool water tight, together with widening the DSP access, may have enabled the entire process of RPV segmentation, transfer to the DSP and final size reduction to be completed underwater. The potential safety benefits from such an approach could be significant and Hitachi-GE was therefore asked to provide an objective assessment.	4.2
RQ-ABWR-1184	Construction (Design and Management) Regulations 2015 Regulation 9 Designer Duties	Early design decisions can fundamentally affect the health and safety of those who will construct, maintain, clean and use a building as a workplace, and those who will decommission the structures. ONR sought assurance of the recognition by Hitachi-GE of its UK statutory responsibilities as a CDM 2015 designer, and of there being a system in place to deliver the same.	4.2
RQ-ABWR-1191	Human Factors In Decommissioning	To provide a Human Factors gap analysis so ONR could fully understand the types of gaps identified and the methods for their resolution, together with evidence that the claim made about the incorporation of space into the design, to assist decommissioning tasks, had been achieved.	4.2

Annex 5
Regulatory Issues / Observations

RI / RO Ref	RI / RO Title	Description	Date Closed	Report Section Reference
RI-ABWR-0001	Definition and Justification for the Radioactive Source Terms in UK ABWR during Normal Operations	The definition of the radioactive source term, namely the nature and amount of radioactivity, is a fundamental part of understanding and being able to control the hazards associated with any nuclear facility. This definition should be based upon a suitable and sufficient justification, which should demonstrate that the derived values are appropriate to be used within the safety case, in whatever capacity is necessary. Failure to adequately define or justify the source term could ultimately mean that the design, operations or controls specified may not be soundly based. It would also prove difficult to demonstrate that associated risks have been reduced So Far As Is Reasonably Practicable.	November 2016	2.3 and 4.3
RO-ABWR-0006	Source Terms	Sets out the regulators' expectations regarding operational states in UK ABWR for the RP to demonstrate that source terms have been reduced So Far As Is Reasonably Practicable (SFAIRP) and that Best Available Techniques (BAT) has been applied. The scope of the regulators' interest in this topic extends to design basis and severe accidents.	April 2017	2.3 and 4.4
RO-ABWR-0011	Safety Case for Spent Fuel Pool and Fuel Route	To define the scope of the Spent Fuel Pool and fuel route safety case to be incorporated into future revisions of the PCSR. The purpose of this Regulatory Observation was to consider the fuel route up to export of the spent fuel from the reactor building.	June 2017	2.3 and 4.4
RO-ABWR-0035	Robust justification for the materials selected for UK ABWR	The choice of materials for a particular SSC of a nuclear reactor is influenced by many competing factors, including: ■ the functional requirements of the SSC; ■ the tolerance/degradation of the SSC in its operating 'environment', and/or: ■ the potential hazards and risks, which must be either eliminated, reduced or controlled. Considering the above factors, and potentially others, it is clear the justification of the most appropriate material selected for a particular SSC requires a balance to be struck which should include a robust demonstration that all of the relevant risks have been considered and reduced SFAIRP.	October 2017	2.3 and 4.4
RO-ABWR-0036	Demonstration that the approach taken to radioactive waste	The approach taken to the management of liquid, solid and gaseous radioactive wastes can involve complex decisions. The chosen regimes	October 2017	2.3 and 4.4

	management reduces risks SFAIRP	must adequately balance the different benefits and detriments of the approach in order to demonstrate that this reduces risks So Far As Is Reasonably Practicable (SFAIRP).		
RO-ABWR-0037	Safety Case for Faults not Directly Related to the Reactor	Required Hitachi-GE to demonstrate that it had identified all buildings, systems, processes and activities which could, in a fault condition, result in a person receiving a significant radiation dose or to the escape of a significant quantity of radioactive material, despite the reactor core being unaffected.	August 2017	2.3 and 4.4
RO-ABWR-0045	UK ABWR – Operational Experience (OPEX)	The RP had not demonstrated sufficiently how it considered and took account of operational experience from BWR plants from around the world including Japan. ONR acknowledged that the UK ABWR is an evolutionary design, incorporating a number of engineered features, which are considered improvements to earlier designs. In addition, ABWRs have been operational for a number of years. This regulatory observation was cross-cutting and of interest to all assessment disciplines. Hitachi-GE was required to: 1. demonstrate adequate knowledge of all BWR and ABWR operational experience across the world; 2. demonstrate the adequacy and robustness of its ABWR technology; and 3. adequately consider operational experience to reduce risks So Far As is Reasonably Practicable (SFAIRP).	March 2017	2.3 and 4.4
RO-ABWR-0054	UK ABWR – Chemical/Process Engineering Design approach	ONR's review identified shortfalls in the Hitachi-GE proposal for the radioactive waste systems and their ultimate decommissioning relating to the J-ABWR use of embedded pipework and Hitachi-GE's approach to the implementation of the recommendations arising from the identification of hazards arising from the radioactive liquid waste systems. The objective of this Regulatory Observation (RO) was to: a) State ONR's expectations related to a Chemical/Process engineering design approach to systems, i.e. the principles, rules, considerations and selection criteria. b) Request Hitachi-GE shows how it will implement a design approach that meets ONR expectations for the design of the UK ABWR.	August 2017	2.3 and 4.4
RO-ABWR-0056	Demonstration that adequate optioneering has been carried out for the removal of Spent Fuel from the Reactor Building	There is a need to show that for spent fuel removal out of the reactor building adequate optioneering has been carried out and that the approach being taken can demonstrate that the design reduces risks So Far As Is Reasonably Practicable (SFAIRP).	March 2017	2.3 and 4.4

RO-ABWR-0064	Design approach to identification and provision of both permanent and temporary features necessary for the adequate control of radioactive contamination across the full lifetime of UK ABWR	It was not initially possible to clearly identify the approach that Hitachi-GE had taken to control radioactive contamination. ONR expects that the UK ABWR should be designed such that permanent and temporary features required to manage and prevent the spread of radioactive contamination, from areas of high designation to those of lower designation, are fully considered.	July 2017	2.3 and 4.4

Annex 6
Assessment Findings

Assessment Finding Number	Assessment Finding	Report Section Reference
AF-ABWR-D-01	Hitachi-GE's generic safety case for decommissioning was based on a strategy of prompt dismantling, with some reliance on Systems, Structures and Components (SSCs) that will be in-situ during station operations to support delivery of decommissioning activities. Whilst this provided sufficient evidence for the purpose of leaving GDA, the generic case did not take account of reasonably foreseeable events (such as a delay to decommissioning timescales) and did not comprehensively capture all the functional and service life requirements for all relevant SSCs to support Post Operational Clean Out (POCO) and decommissioning. Therefore the licensee shall ensure that when considering decommissioning: ■ The UK ABWR civil structures are designed such that all relevant safety functions can be delivered for as long as necessary, should the timescales of decommissioning need to be extended beyond the plan provided in the generic safety case. ■ Adequate consideration is given to the requirement for auxiliary systems that support station operations to contribute to POCO and decommissioning, noting the potential for more onerous demands to be placed on some SSCs during POCO and decommissioning than in normal operations.	4.2
AF-ABWR-D-02	Hitachi-GE's generic safety case claimed that the Human Factors considerations for maintenance of replaceable items during the UK ABWR's operations are representative and bounding of the intended decommissioning activities. As substantiation of this claim is dependent on site specific information, the licensee shall at appropriate times during detailed	4.2

	design, construction and operation of the UK ABWR: ■ Review the decommissioning plan and maintenance schedule, to confirm whether the Human Factors considerations for maintenance of replaceable items during station operations are, so far as is reasonably practicable (SFAIRP), representative and bounding of the intended decommissioning activities. ■ Substantiate that appropriate working conditions can be provided to operators SFAIRP during decommissioning, taking into account provision of sufficient space, supporting services and the intended decommissioning methods.	
AF-ABWR-D-03	Hitachi-GE's generic safety case identified the potential for advanced modular construction techniques to be used in building the UK ABWR and the possibility that such techniques may have negative impacts for decommissioning. Should the licensee decide to use advanced modular techniques in construction of the UK ABWR, it shall demonstrate that it has considered all reasonably practicable measures to minimise any negative impacts from these techniques for decommissioning, including a consideration of: ■ Unobstructed egress routes for equipment and items to be removed during decommissioning ■ Sufficient space for operators to undertake decommissioning tasks ■ Engineering of walls to enable them to be safely removed to assist decommissioning	4.2
AF-ABWR-D-04	Knowledge management is of key importance to decommissioning, given the need to maintain an accurate understanding of the 'as built' plant over long durations.	4.2

	Whilst Hitachi-GE's generic safety case provided sufficient recognition of knowledge management, the eventual method will be highly reliant on site-specific conditions and the licensee's operational choices. Therefore the licensee shall develop, so far as is reasonably practicable, robust arrangements to capture relevant knowledge for the delivery of decommissioning throughout all the preceding stages of the plant's life. These arrangements should ensure the licensee maintains an accurate understanding of the 'as built' plant and radioactive wastes over the required timescales, including any significant design changes, process modifications and any departures from the expected plant conditions.	

Annex 7
Minor Shortfalls

Minor Shortfall Number	Minor Shortfall	Report Section Reference
MS-ABWR-D-01	The future licensee should address the reported findings of RWM Ltd and ensure the disposability of decommissioning HAW at the UK's planned GDF is addressed within its choices on detailed design and operation of the UK ABWR.	4.2