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UK ABWR

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UK ABWR Generic Design Assessment

Generic PCSR Chapter 31 : Decommissioning

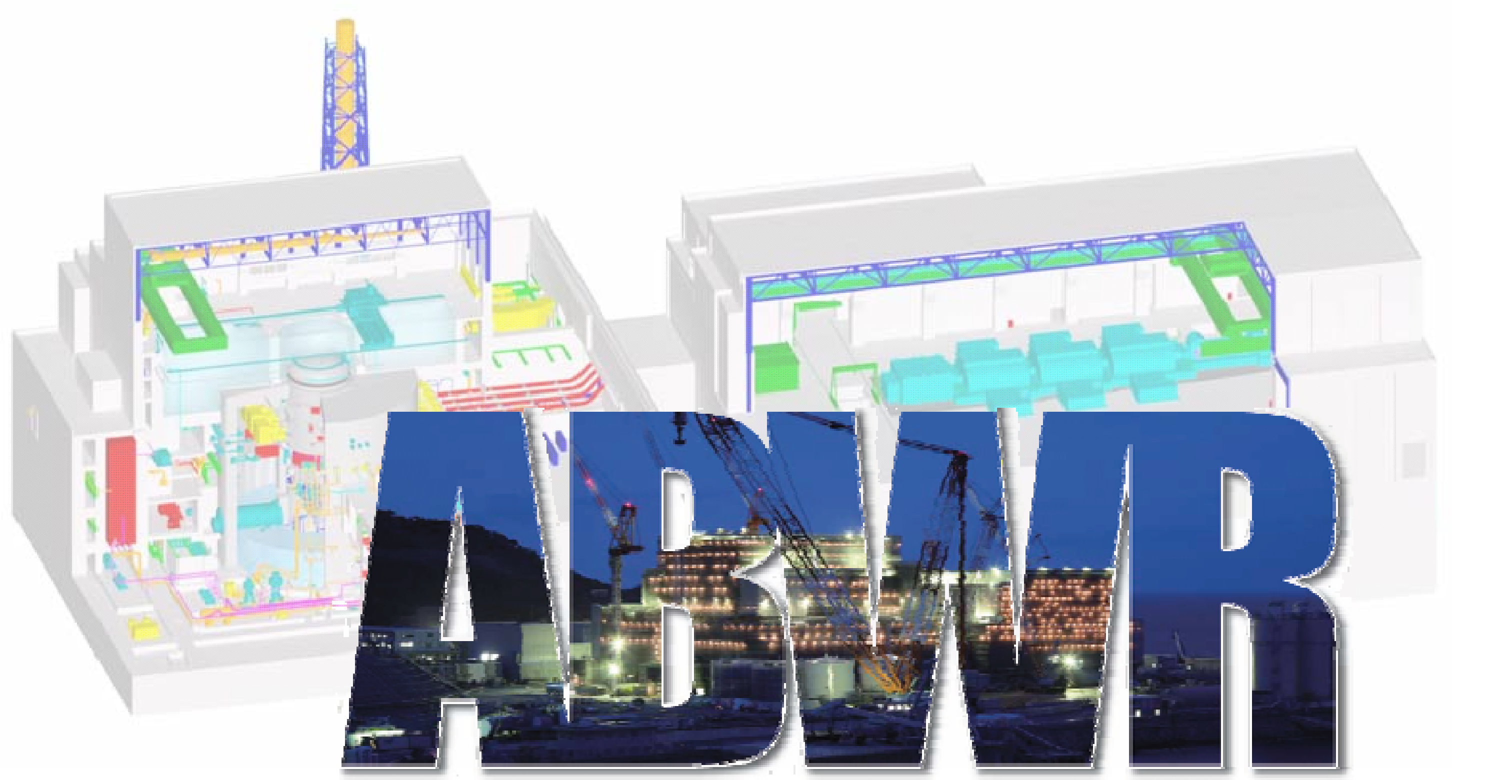

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Table of Contents

31.1 Introduction

This is a Pre-Construction Safety Report (PCSR) to facilitate future decommissioning of the United Kingdom Advanced Boiling Water Reactor (UK ABWR) for the Generic Design Assessment (GDA) by the Office for Nuclear Regulation (ONR) and Environment Agency (EA). Although decommissioning is the last stage in the overall lifecycle of a facility, it must be taken into account at the planning and design stages. This includes sections and subsections covering the baseline of the future decommissioning of UK ABWR in a safe and environmentally acceptable way to meet both the expectations and requirements set forth by the ONR and Environment Agency.

The decommissioning of the UK ABWR will be the responsibility of the future licensee. However, as required by the GDA process, Hitachi-GE needs to demonstrate that the UK ABWR design considers decommissioning, that it can be decommissioned using currently available technology and wastes minimised with an appropriate disposal route.

31.1.1 UK Approach

Under the current UK arrangements, there is a regulator requirement placed upon the future licensee to demonstrate that the hazards and risks associated with their operations are well known and adequately controlled. Similarly they are obliged to assess and minimise the impact of any operations upon environment.

For the decommissioning of nuclear facilities, various stakeholder responsibilities are:

- ✓ Government – To determine policy, in the light of international agreements and guidance, and prepare statutory legislation.
- ✓ Regulators – To enforce Government policy and publish guidance which interprets Government policy.
- ✓ Licensee – To prepare appropriate decommissioning strategies and plans, in compliance with Government policies and legislation and regulatory requirements/guidance. In the case of new build UK projects, the Operator also has a responsibility to put in place arrangements to ensure adequate funding of subsequent decommissioning liabilities.

International and national guidance is identified in [Ref-1][Ref-2][Ref-3][Ref-4]. One of the key pieces of legislation during the planning phase of a new plant is the Energy Act 2008 (The Act). The Act places specific obligations upon the licensee. Section 45 of the Act states that in applying for a nuclear site licence they are required to:

- ✓ Give written notice of the application to the Secretary of State, and prepare and submit to the Secretary of State a Funded Decommissioning Programme (FDP).

The Department of Energy and Climate Change (DECC) has issued guidance to assist those producing a FDP. The guidance presents a number of assumptions regarding the means by which waste may be managed and disposed of and decommissioning carried out by a new nuclear power station operator. These assumptions define a generic lifecycle plan for new nuclear power stations known as the “Base Case”.

The Base Case assumes prompt decommissioning of the power station with no care and maintenance period after the station has been shut down and before decommissioning takes place. It is open to

Operators to propose a care and maintenance period in their Decommissioning Waste Management Plan (DWMP) submissions, but the inclusion must be agreeable to the regulators and approved by the Secretary of State as part of the operator's FDP.

31.1.2 Preferred Approach and Key Assumptions

For GDA, the decommissioning strategy is defined as:

- ✓ Decommission the site promptly and continuously as far as external constraints will allow.
- ✓ Simplify the plant and systems which will remain active during decommissioning to allow the simplification of the site arrangements and the structure of the decommissioning organisation.
- ✓ Dispose of LLW, ILW, spent fuel and all other decommissioning wastes to authorised off-site facilities as soon as these facilities are available.
- ✓ De-license the site.

31.1.2.1 Assumptions

The assumptions made in developing the approach to decommissioning are:

- ✓ Sixty years' operating period of UK ABWR.
- ✓ Decommissioning of a reactor begins at the point that the reactor is shut down with no intention of further electricity generation.
- ✓ After determination of permanent shutdown, decommissioning works will be conducted when possible. For most buildings there is no period of care and maintenance to allow radioactive decay, this strategy is referred to as prompt decommissioning.
- ✓ Existing buildings and facilities will be utilised for decommissioning purposes where this is appropriate and ensures risks are ALARP and wastes minimised.
- ✓ The walls of buildings will be utilised as boundaries for decommissioning. They are utilised for prevention of spread of contamination, irradiation control and radiation protection. If the walls of buildings are not utilised, usable temporary containment and shielding will be established. Protection will be provided to prevent contamination of the walls where appropriate.
- ✓ Any Low Level Waste (LLW) / Very Low Level Waste (VLLW) or industrial waste generated will be disposed of immediately.
- ✓ Packaged ILW will be temporary stored on the site for a period, and they will be transferred to the waste disposal site.
- ✓ The strategy reflects only currently available technologies.
- ✓ There remains no centralised UK or regional off-site interim store available for ILW or spent fuel.
- ✓ It is assumed that ILW will remain onsite till after decommissioning has finished. Spent Fuel will remain onsite for up to 140 years after the end of generation [Ref-5].
- ✓ Decommissioning is assumed to end when all station buildings and facilities have been demolished and the site has been returned to an end state that has been agreed with the regulators and planning authority.

31.1.3 Scope

The objective of decommissioning a nuclear power station is to transit the site from its operational state to an agreed end state.

It is essential that decommissioning is planned in detail prior to station shutdown to ensure that decommissioning operations can be implemented in a safe manner. Once the reactor has shut down permanently, all of the activities carried out on and around the site will be part of the "Decommissioning Scope". This scope includes:

- ✓ Pre-closure Planning
- ✓ De-fuelling and Spent Fuel Management
- ✓ Maintenance and modification of the site infrastructure and services. This will include activities concerned with site security, site monitoring, maintenance activities, etc.
- ✓ Dismantling and demolition
- ✓ Waste management (both radioactive and conventional hazardous wastes)
- ✓ Storage of ILW and spent fuel
- ✓ Site remediation activities
- ✓ De-licensing

31.1.4 Aims

The purpose of this chapter is therefore to:

- ✓ Identify features of the UKABWR Design that support Decommissioning.
- ✓ Identify wastes likely to be generated through operations and decommissioning and determine possible disposal routes.
- ✓ Describe the approach to decommissioning of the UKABWR.
- ✓ Identify claims and hazards for decommissioning.
- ✓ Provide confidence that the UK ABWR can be decommissioned safely.

Four Topic Reports have been produced to support the chapter (along with linkages to other chapters of the PCSR) these being:

- ✓ Topic Report 1: Decommissioning Schedule [Ref-6]
- ✓ Topic Report 2: Decommissioning Plan for Main Buildings [Ref-7]
- ✓ Topic Report 3: Decommissioning Procedure for Typical Equipment [Ref-8]
- ✓ Topic Report 4: Applied Technology Evaluation [Ref-9]

Further work has been identified in Section 31.9 to further underpin the demonstration of the safety claims for the design, decommissioning schedule, decommissioning process, waste identification/storage/processing and disposability.

31.2 Safety Claims

The safety case for decommissioning of UK ABWR is based on a single high level safety claim (i.e. UK ABWR can be decommissioned safely), supported by five sub-claims, as shown below:

Claim	Sub-claim	PCSR Section
Decom-SFC 1 - UK ABWR can be decommissioned safely	Decom-SFC 1.1 - The UK ABWR design incorporates features that facilitate decommissioning	31.3
	Decom-SFC 1.2 - Viable disposal routes are available (or will be available) for all decommissioning wastes	31.4
	Decom-SFC 1.3 - UK ABWR can be decommissioned using today's technology	31.5
	Decom-SFC 1.4 - Faults and Hazards during decommissioning will be identified, assessed and all risks shown to be As Low As Reasonably Practicable	31.7
	Decom-SFC 1.5 - Appropriate decommissioning plans/ strategies are in place, and will continue to be developed by the future licensee.	31.5

The sections below present preliminary arguments that support each of these claims. These sections also present a summary and reference to evidence that is available at the present time. Future work is identified in Section 31.9.

31.3 UK ABWR Design for Decommissioning

31.3.1 Evolution of Design

Boiling Water Reactors (BWR) have been in commercial operation since the 1960s. Over that time there have been many improvements to the design of the reactor containment and the configuration of the cooling systems. Over the operational lifetime of these reactors a number of other improvements have been incorporated into the designs which serve to minimise operator dose uptakes and help facilitate the decommissioning process.

31.3.1.1 Material Selection

A key aspect to lessen the radiological exposure to workers during decommissioning is to consider at the outset the materials used in the design, construction and operation of the UK ABWR. There are certain materials particularly those with a high cobalt content that are prone to activation by neutrons. Additionally, reactor chemistry plays a key role in minimising contamination in the reactor circuit. The details of the water chemistry are presented within Chapter 23.

Specifically, the following material considerations have informed the design:

- ✓ Selection of construction materials to reduce the levels of trace elements in materials that can become activated i.e. the use of stainless steels and Ni-based alloys with low-Cobalt contents that are in contact with the reactor water are applied to the structure.
- ✓ Selection of materials, specifically the identification of alternate materials to Stellite® alloy are applied to the structure, to prevent the activation of stable Cobalt.
- ✓ Prevention of the spread of contamination via the use of corrosion resistant materials are adopted for the core internals and piping to protect against loss of containment.

31.3.1.2 Leakage and Escape of Radioactive Materials

During the operation of the UK ABWR it is essential that any leakage of radioactive materials is detected and contained. Bunds are to be constructed in each area/room where necessary in order to prevent spread of contamination in the case of leakage of water. Where bunds are installed, floors will be designed to slope to direct any spills to a drain with appropriate means of monitoring or detection.

Containment of leakages will be provided with the use of features such as the curvature of concrete floors and the use of floor slopes. Double isolating of drain valves will be included to aid the containment of liquids. Where judged to be necessary, floors and other surfaces that may be exposed to leaks are to be waterproofed.

In doing this, the UK ABWR design minimises the potential for undetected leakages into concrete or to ground which would increase the amount of waste and radiological dose to workers in decommissioning. Specific liners/bunds or containment is described in Chapter 10: Civil Works and Structures.

31.3.1.3 Design Improvements to Assist Decommissioning

The UK ABWR has been designed to enable an effective decommissioning process to be applied. The purpose of these features is to improve access, transport routes, decontamination and to reduce the occupancy times (and thus dose) during decommissioning. The incorporation of these features will enable the removal of significant pieces of equipment which will contribute to an optimised decommissioning process as described below;

- ✓ Reduction of the degree of surface contamination via the treatment of concrete surface for ease of decontamination. Concrete surfaces where there is a possibility of contamination will be coated. In addition, the Spent Fuel Pool (SFP) will be fitted with a steel liner [Chapter 10].
- ✓ Metal surfaces in some systems will be pre-treated to prevent contamination [Ref-7] using techniques such as surface polishing.
- ✓ Laydown space and local service areas are provided for maintenance and replacement activity of equipment. Adequate hallways and equipment removal paths, including vertical access hatches are provided for moving equipment from its installed position to its service area or out of the building for repair.
- ✓ The need for embedded pipework, ducts and equipment in floors and walls will be designed out where reasonably practicable.
- ✓ Where possible, the installation of equipment in expected high dose fields has been minimised thus reducing the time of operator entry to these areas.
- ✓ Primary coolant purification system (e.g. CUW) and coolant demineralizer will be applied to remove impurity or activated particles.

It is recognised that decommissioning operations will generate significant quantities of waste materials. Therefore, to assist in the management it is expected that waste will be temporarily stored within existing buildings (where reasonably practicable).

31.3.2 Decommissioning Practicability

Decommissioning of the UKABWR has been considered and high level plans are provided within [Ref-6]. Presented here is an overview of an approach that can be utilised given the current technologies available [Ref-9].

31.3.2.1 Dismantling of Main Buildings [Ref-7]

Dismantling plans for the main buildings such as the Reactor Building (R/B), Turbine Building (T/B and the Radwaste Building (Rw/B) under normal conditions are described in [Ref-7].

The demolition of building structures is well known and understood. It is expected that demolition operations will only be performed once the structures have been confirmed to be radiologically clean. As such, it is not expected that demolition of buildings will present a radiological hazard.

Decontamination is again well understood and it is expected that techniques such as washing and abrasion will be used to remove loose and fixed contamination [Ref-9].

31.3.2.2 Dismantling of Reactor Internals [Ref-8]

Decommissioning of the Reactor Internals is not scheduled to begin until the Spent Fuel (SF) has been removed from the Spent Fuel Pool (SFP). It is currently assumed that the fuel will require at least five years' cooling before transfer to an interim store. This is beneficial as it allows for the decay of short lived radionuclides.

The dismantling of the Reactor Internals will occur following a chemical clean-up of the RPV and associated cooling circuit to remove loose contamination. The whole process is anticipated to occur underwater by remote means. This is beneficial as the presence of the water will provide radiation shielding.

It is anticipated that the processing of the waste generated during dismantling will take place local to the segmentation operations. At present a strategy is required for the packaging and removal of the internals for interim storage.

31.3.2.3 Dismantling of the Turbine [Ref-8]

To gain access to the turbine it will be necessary to remove the generator. It is not expected that the generator will be contaminated and its demolition is not expected to present a radiological hazard. It is possible that the turbine will have low levels of contamination as it will have been in contact with the steam. Therefore, prior to removal of the turbine it is anticipated that it will be decontaminated using techniques such as wiping down to remove loose contamination. It is expected that the lifting operations required to remove the turbine will present the most significant hazards.

31.3.2.4 Dismantling of Spent Fuel Storage Pool [Ref-8]

Prior to the demolition of the SFP, the pool furniture will be removed. The steel liner will be decontaminated most likely via pressure washing. It is expected that an abrasive technique such as shot blasting will be utilised to decontaminate the pool structure. It is expected that the demolition of the cleaned structure will utilise well known techniques.

31.3.2.5 Dismantling of the Reactor Pressure Vessel [Ref-8]

The RPV is to be dismantled once the internal components have been removed. The RPV is to be decontaminated internally and externally and filled with water to provide shielding. It is expected that the central portions of the RPV will have the greatest levels of radiation. It is anticipated that the RPV will be cut up remotely and the water level gradually reduced as dismantling progresses. Further size reduction will occur in the Dryer Separator Pool. It is anticipated that the processing of the waste generated during dismantling will take place local to the segmentation operations. At present a strategy is required for the packaging and removal of the RPV sections for interim storage.

31.3.2.6 Dismantling of Reactor Internal Pump (RIP) [Ref-8]

Parts of the RIP casing forms part of the RPV and will be dismantled with the RPV. However, the RIP internals can and will be decontaminated and removed prior to RPV demolition as this will be routinely undertaken as a maintenance activity.

31.3.3 Further Work

Further work is necessary to demonstrate the full practicability of decommissioning and ensure the design is optimised for decommissioning. The list below also indicates which Topic Report (TR) will address the issue (Section 31.9). Aspects to be considered include:

- ✓ That the use of “sumps”, “u-bends”, “traps” etc. in fluid bearing systems which cannot be drained has been avoided where practical to do so. (TR “Design for Decommissioning”)
- ✓ Optimisation of the design of fluid bearing systems (including air/ventilation) to reduce / avoid low-flow or stagnant areas which might allow entrained particulate to deposit. (especially where there’s potential for particulate to be radioactive). Where such areas are unavoidable, a demonstration that it is possible to remove/re-mobilise sediments (so they can be captured on system filters) prior to system maintenance or dismantling. (TR “Design for Decommissioning”)
- ✓ That the design incorporates suitable clearance/ access space for workers to dismantle equipment in situ and/or installed hoists, cranes and egress routes to allow equipment to be removed for dismantling. This can be confirmed making use of the UK ABWR 3D model. (TR “Design for Decommissioning”)
- ✓ An identification of which buildings/areas/systems will need to remain active beyond the end of power generation. (TR “Decommissioning Plan”)
- ✓ A determination of engineering utilities and support systems to allow redundant systems to be depowered and deactivated without affecting remaining operating areas. (TR “Decommissioning Plan”)
- ✓ A determination of which installed cranes and hoists may be required to support decommissioning operations. For the identified cranes and hoists a demonstration that their operating life will be suitable to encompass there full range of operating and decommissioning uses. (TR “Decommissioning Plan”)
- ✓ A determination of which building services will be required to support decommissioning and a demonstration that their design is fit for all envisaged life cycle phases. (TR “Decommissioning Plan”)
- ✓ A confirmation that where possible, embedded pipework has been minimised. (TR “Design for Decommissioning”)
- ✓ Development of a strategy for the removal of the RPV and the internal structures. (TR “Decommissioning Strategy”)

31.4 Waste Management

The sub-claim made above that ‘viable disposal routes are available (or will be available) for all decommissioning wastes’ is considered to be justified based on the following:

- ✓ The types and volumes of decommissioning waste have been assessed, allowing a number of waste streams to be identified.
- ✓ Viable proposals for waste packaging have been identified for all identified waste streams, although some further work is required for higher activity metal waste (e.g. reactor internals and control rods) once the source term has been confirmed.
- ✓ Waste management strategies for gaseous, liquid and solid decommissioning wastes have been defined and are considered to lead to no significant obstacles to decommissioning.
- ✓ A robust and conservative estimate of the radionuclide inventory has been developed (again subject to confirmation of the source term during Step 4 GDA).
- ✓ Radioactive Waste Management Limited (RWM) [a subsidiary of the Nuclear decommissioning Authority (NDA)] have been consulted and preliminary work indicates that there are no ‘significant issues that challenge the fundamental disposability of the wastes …. expected to be generated from operation of a [UK ABWR]’.

These arguments are discussed in more detail in the subsections below:

31.4.1 Waste Types and Volumes

31.4.1.1 Higher Activity Wastes (HLW and ILW)

The higher activity wastes generated during decommissioning will comprise activated steel components, which have been grouped in the following streams:

- ✓ Reactor Pressure Vessel internals:
    - o This stream consists of in-vessel stainless steel structures that support the reactor core and its safety systems. Because the neutron flux falls rapidly with distance from the core, this material has a wide range of neutron activation levels.
- ✓ Reactor Pressure Vessel:
    - o This stream consists of the carbon steel reactor vessel and the stainless steel liner on the inside of the vessel.

Decommissioning ILW will also include a small volume of stainless steel filter housings, which have been included in the two decommissioning streams above.

Numerous types of ‘operational’ ILW will also continue to be created during decommissioning, or will require treatment and disposal during the decommissioning phase. These have been identified as:

- ✓ Condensate Filter Facility (CF) Crud

  - Crud is solid material made up of corrosion and erosion products from the reactor internals (primarily derived from steel alloys) and other water circulation systems within the plant. CF Crud arises in the condensers after the steam has passed through the turbine.
- ✓ Low Conductivity Waste (LCW) Crud
  - The LCW system collects and filters wastes from various sources including drains in the Reactor Building (R/B), Turbine Building (T/B) and Radwaste Building (RW/B). LCW Crud arises from backwashing the filters in the LCW system.
- ✓ Reactor Water Clean-up (CUW) Resin
  - Ion-exchange resins are used to remove dissolved activity from reactor coolant, Spent Fuel Pool (SFP) water or other liquid streams. CUW Resin is a powder based polystyrene resin.
- ✓ Fuel Pool Clean-up (FPC) Resin
  - FPC Resin is a powder based polystyrene resin.
- ✓ Post-operation Decontamination (DEC) Resin
  - DEC Resin is a bead based polystyrene resin.
- ✓ Hafnium (Hf) Control Rods
  - There are two variants of control rod; in the Hafnium variant the cruciform control rods are made up of a stainless steel sheath which contains flattened stainless steel tubes filled with Hafnium, a neutron absorber.
- ✓ Boron Carbide (B_4C) Control Rods
  - The other control rod variant is made up of stainless steel tubes in each wing of the cruciform filled with compacted boron carbide powder.
- ✓ Mixed Metal ILW
  - This stream includes activated metal, including Local Power Range Monitoring (LPRM) assemblies, Start-up Power Range Monitor (SNRM) assemblies and neutron source units (which contain Antimony and Beryllium).

Table 31-2 presents the volume, or mass, of the higher activity wastes that are expected to be generated during decommissioning [Ref-5]. Spent fuel will also be exported during the decommissioning phase. Spent fuel management is discussed in more detail in PCSR Chapter 32.

31.4.1.2 Lower Activity Wastes (LLW and VLLW)

Low Level Waste (LLW) and Very Low Level Waste (VLLW) will be generated during decontamination, de-planting, and demolition activities during decommissioning. Waste in this category will comprise contaminated concrete and metal, including heat exchangers, tanks, valves, pipes, pumps, filters, carbon delay beds, etc.

Table 31-3 presents the volume, or mass, of LLW and VLLW expected to be generated during decommissioning [Ref-10].

31.4.2 Waste Packaging

To support the sub-claim that disposal routes are available for all wastes anticipated during decommissioning of the UK ABWR, standard RWM waste packages have been identified for all identified waste streams, and there has been no need for novel or bespoke packages to be developed. Table 31-2 identifies the waste packages proposed for each of the waste streams that will arise during decommissioning (including RWM $3m^3$ drum, $3m^3$ box and 4 metre box).

Work is still on-going to confirm the appropriate packaging and processing requirement for the highest activity solid waste streams identified (e.g. control rods) which will generate significant decay heat. An additional decay cooling period may be required before the waste can be grouted, or an alternative solution may be required. It will not be possible to confirm this until the source term is confirmed during Step 4 of GDA.

31.4.3 Waste Management Strategies

An integrated Waste Strategy has been produced which covers waste management during both the operational and decommissioning phases [Ref-11].

31.4.3.1 Gaseous Waste

Radioactive gaseous waste generated during decommissioning will be discharged via the HVAC system, using local, temporary filtration and extract where appropriate. Where HVAC systems are required during both operation and decommissioning phases (e.g. ventilation stack), the design life of the system is assumed to be sufficient to support decommissioning. Suitable measurement and monitoring of radioactive discharges will be required to ensure that the releases are both ALARP and BAT.

31.4.3.2 Liquid Waste

Radioactive liquid waste generated during the decommissioning phase will be treated either by using installed equipment from the operating phase, or using temporary waste treatment facilities, as appropriate. The types of radioactive liquid waste anticipated include:

- ✓ Effluent resulting from equipment flushing and draining
- ✓ Effluent from floor drains
- ✓ Liquid waste from system decontamination
- ✓ Decontamination waste solution after dismantling and decontamination of equipment

31.4.3.3 Solid Waste

Radioactive solid waste generated during decommissioning will be processed and managed in accordance with its activity, size and material properties. It is proposed that a decommissioning waste treatment facility will be installed in the Turbine Building to facilitate solid waste processing [Ref-7]. It is assumed that ILW will be managed close to the location of its generation.

The types of radioactive solid waste anticipated (including that generated during preparation for decommissioning) include:

- ✓ Dismantled equipment and structures
- ✓ Spent resin and cruds
- ✓ Combustible miscellaneous solid waste
- ✓ Non-combustible miscellaneous solid waste (metal waste)
- ✓ Concrete

The T/B waste management facility is expected to process waste in the following ways:

- ✓ Size Reduction
  - o Items too large to fit into standard waste containers will be size reduced. The available techniques for size reduction have been reviewed in Topic Report 4 [Ref-9], which concludes that viable techniques are currently available and have operating experience from nuclear decommissioning projects.
- ✓ Volume reduction
  - o Facilities will be provided to compact waste to reduce its volume in line with the waste hierarchy. The suitability of compaction to reduce the volume of each waste will be decided on a case-by-case basis.
- ✓ Decontamination
  - o The aim of decontamination is to reduce the activity associated with waste items, to reduce dose to workers during decommissioning and to reduce the amount of higher category waste and hence reduce the cost of disposal. However, the amount of decontamination performed needs to be balanced against other factors such as secondary liquid wastes generated and dose to workers during the decontamination process itself. The techniques available for decontamination methods are reviewed in Topic Report 4 [Ref-9], which concludes that an adequate range of techniques are available to cover all anticipated decontamination requirements.

31.4.4 Radionuclide Inventory

A key step in demonstrating that all wastes can be adequately processed, and eventually disposed of, is an understanding of the likely activity associated with each waste. This allows processing, storage and disposal options to be identified and appropriate protection measures to be defined. A radionuclide inventory for each waste stream anticipated during decommissioning has been produced in collaboration with NDA RWM, [Ref-5] who concluded that (based on Step 3 data) a robust and conservative estimate of the radionuclide inventory has been developed.

Further work is required in this area to resolve the current uncertainties in the source term. This work is on-going and will be completed during Step 4. However, significant conservatisms were included within the current disposability assessment, which give confidence that this conclusion will remain valid.

31.4.5 Disposability Assessment

In line with regulatory guidance [Ref-12], HGNE have obtained a view from the NDA (as the authoritative source in the UK on providing such advice) on the disposability in a geological disposal facility of any proposed arisings. The Disposability Assessment produced by RWM [Ref-5] concluded that there are no ‘significant issues that challenge the fundamental disposability of the wastes …. expected to be generated from operation of a [UK ABWR]’. Furthermore, no ‘orphan’ wastes (i.e. those wastes for which no viable disposal option exists) have been identified. As noted above, further work will be required in this area to finalise the disposability assessment based on the updated source term data, expected in Step 4 of GDA.

31.5 ABWR Decommissioning Strategy [Ref-13]

31.5.1 Objective

The objective of decommissioning is to transit the site from its operational state to an agreed end state. The hazard the facility poses is to removed progressively, giving due regard to security considerations, the safety of workers and the general public, and protecting the environment.

Depending on what subsequent use for the site is planned, this end state could be one of minimal visible sign that the station was there, i.e. sections of buildings can remain in the ground but the visible surface is landscaped. All operational plant, systems and facilities will be processed into a form ready for final disposal at an authorised location. All radioactive or hazardous waste will be removed down to agreed levels. The site can then be de-licensed for alternative use.

31.5.2 Principles

The actual decommissioning objective and site end state will be agreed based on the subsequent use of the site. In achieving, and planning to achieve, this agreed end state, a set of principles which are set out below have been applied.

- ✓ Strategies and plans will be compliant with UK Government policies and legislation, including the policy aim of sustainable development. Sustainability should be considered such that unduly restrictive burdens are not left for future generations. Strategies and plans should take account of the views of stakeholders.
- ✓ The safety and protection of the public, the workforce and the environment are the key drivers and decommissioning should be managed in accordance with the ALARP principle to ensure an optimal level of protection taking into account all relevant factors.
- ✓ The decommissioning plan should be developed to be “Fit for Purpose” in terms of the technology assumed, the organisational arrangements to be used and staff training and skill levels required.
- ✓ The best appropriate scientific and technical knowledge should be used to inform the decommissioning plan but technologies and techniques which are planned to be deployed should be readily available and easy to use. Simple and flexible solutions should be sought in preference to complex ones.
- ✓ The decommissioning plan should focus on tasks and hazards, aiming for a progressive reduction in hazard, not on plant systems and should recognise that decommissioning is a project and not an on-going operational activity.
- ✓ Strategies and plans need to recognise that the output of the decommissioning process is radioactive and non-radioactive waste for recycling or disposal (and potentially reuse), and that decommissioning strategies and plans should be consistent with the Waste Management Strategy.
- ✓ BAT are to be applied to minimise volumes of radioactive wastes which are created, particularly ILW wastes. BAT will be used in the management of discharges from the site, though it is recognised that adoption of the BAT solution to management of some wastes may result in short term increases in discharges of some radionuclides.

- ✓ After reactor closure, the overall philosophy of the site will be changed from “safe, operational excellence and high availability”, requiring the use of complicated and integrated systems to one of “safe, simple, self-contained, economic and fit for purpose approaches with work only undertaken when and where needed”. Such a philosophy can be characterised by:
  - Decoupling of systems so that they are self-contained and independent, with minimal interactions.
  - The idea that providing new equipment and facilities may be preferable to modifying existing equipment and facilities.
  - Using appropriate “low-tech” and robust solutions rather than high-tech ones.
  - Recognising the changing hazards and risks on the site and reflecting these in the safety objectives and approaches. The hazards caused by high levels of radioactivity in fuel, high temperatures and pressures and large numbers of live power circuits reduce dramatically once the reactor is closed down. However, the safety aspects of decommissioning, involving significant manual work and a constantly changing physical environment will create different challenges.
  - Transforming the organisation from having an operational focus to one that has a project focus where scope, cost and schedule drive the thinking. Integral to this change will be the development of a project focused safety culture to recognise the changed and evolving nature of the hazard from that which existed during routine operations. It will ensure that projects are planned to take account of the actual hazard that exists upon commencement and the additional hazard that may be introduced during performance of the project.
  - Building an appropriate workforce (both employees and contractors) with the right skills and attitudes for decommissioning.
- ✓ Strategies and plans will be reviewed and updated on a regular basis and information relating to these plans, including their costs, schedule and implementation will be recorded and preserved.
- ✓ The decommissioning fund accumulated during the reactors’ life must be adequate to pay for the planned decommissioning of the site and management of all waste arisings in line with the waste hierarchy.
- ✓ The strategy should be developed so as to prevent or avoid risks wherever possible, and to allow mitigation of any residual risks.
- ✓ Any new facility will be designed, built and operated so as to minimise decommissioning and associated waste management activities and related costs.
- ✓ Decommissioning activities will be carried out as soon as reasonably practicable, taking into account all relevant factors.
- ✓ Throughout the whole life-cycle of a facility the documents and records that might be required for decommissioning purposes should be identified, prepared, updated and retained.

These decommissioning objective and principles, and the subsequent development of this strategy are considered to be consistent with the national policy and regulatory expectations.

31.5.3 Decommissioning Strategy

31.5.3.1 Strategic Options

At the highest, strategic level, decommissioning options revolve around two key issues:

- ✓ When to dismantle plant systems, structures and components and,
- ✓ Where (and when) to dispose of the waste (including the possibility of leaving it on the site).

Four high level decommissioning options have been identified. These options align with IAEA guidance [Ref-1] and international practice. The options considered for the UKABWR were:

- Option 1: Prompt/continuous dismantling
- Option 2: Deferred dismantling
- Option 3: Deferred dismantling with no early deplanting in active areas
- Option 4: Entombment

31.5.3.2 Option Discussion

These four options have been reviewed under [Ref-14]. The results are presented below. Option 4, Entombment, was discounted from detailed assessment. It was considered that the difficulties and disadvantages of this option outweighed the benefits, particularly in the areas of, stakeholder acceptance and financial risk. It was also considered that this option did not align with the assumptions and perceived expectation of the DECC Base Case with regard to remediation, de-licensing and restoration of the site to "green field" or its state prior to construction. The remaining three options, all of which involve removal of radioactive waste from the site such that it can be released from regulatory control, were scored against various factors with the result that Option 1 was allocated the highest score. Consequently, Option 1 has been adopted as the preferred decommissioning strategy.

31.5.4 Implementation of the Preferred Decommissioning Strategy

31.5.4.1 Introduction

The section below presents an overview of the decommissioning process for UKABWR and how it could be accomplished based on currently available experience and technology without the need for any future developments or R&D. Further information and developments (e.g. improved technology), both in the UK and internationally, may prompt changes in order to improve safety and environmental protection or reduce costs. Such potential improvements will need to be kept under review by the Licensee organisation throughout the life of the plant and will require incorporation into subsequent Periodic Safety Reviews and updates of the Decommissioning Plans.

The availability of the GDF to receive wastes means that the preferred Prompt decommissioning strategy takes place over an extended period, though the power plant is removed and the wastes destined for GDF are placed in a passively safe form as quickly as is practicable. The entire decommissioning period can be divided into phases of similar works; this phasing will form the basis of the following high level description of how the strategy is expected to be implemented.

31.5.4.2 Before End of Generation

The main focus of this period is the operation of the plant to generate power. During site operations measures will be applied to minimise the radiological wastes arising from operations. Despite this, waste arisings are expected, some of which will require geological disposal for which no disposal route will be available at that time. Hence, early in the ABWRs operational life, waste storage facilities will be required for the following:

- ✓ An ILW interim store, for storage of ILW wastes packaged in a form acceptable for disposal in the GDF when available, and
- ✓ A Spent Fuel Store, for storage of spent fuel removed from the Spent Fuel Storage Pool (after a suitable period of cooling) and based on a dry cask storage system.

Packaged ILW waste and spent fuel arising from operation of the site will be transferred to these facilities on a campaign basis. LLW, VLLW and non-radiological wastes arising during operation of the site will be transferred to off-site disposal facilities.

31.5.4.3 Immediately After End of Generation

After generation operations have been completed, fuel will be transferred from the reactor into the Spent Fuel Storage Pool for a period of storage and cooling. It is recognised that the cooling period has no effect upon the ability to decommission the ABWR but will have an impact upon the planning and the timing of certain operations. This will be an issue for the licensee and has minimal impact upon the design requirement i.e. the need to maintain cooling to the SFP.

A key assumption is that, whilst fuel remains in the Spent Fuel Storage Pools, many supporting systems that serve the Reactor Building will need to remain operational. Hence little dismantling of plant systems is planned for this period.

It may be possible to carry out modifications to those systems supporting the management of fuel in the Spent Fuel Storage Pools, or to install alternative temporary systems, so that the Spent Fuel Storage Pool can be made stand alone and isolated from the main plant systems. Subject to development of an appropriate safety case, this would allow installed systems to be declared redundant and available for early dismantling. This may be beneficial if it is determined that the spent fuel needs to remain in the Spent Fuel Storage Pool for an extended period, but is not currently part of the assumed implementation of the decommissioning strategy.

As power generation ends, the organisation will need to recognise that changes to its operational structure will be required as the nature of the work changes from operations to decommissioning. It is expected that an increase in capability will be required and that new skills will need to be developed. The early decommissioning works are expected to comprise:

- ✓ Post Operational Clean Out (POCO)
- ✓ Chemical Decontamination
- ✓ Thermal Insulation Removal
- ✓ Alternate Effluent Discharge Arrangements

- ✓ Characterisation

31.5.4.3.1 Post Operational Clean Out (POCO)

POCO is the removal of working fluids, resins and other operational material (radioactive and non-radioactive) at the end of a facility's operational life, and the management of the resulting waste materials. Systems will be purged, vented and drained as required and some systems flushed to remove hazardous residues. One of the main drivers is to deactivate as many areas as possible, as soon as possible, so that they are in a passive state. The work is typically carried out by plant operators, making best use of their knowledge, and generally performed using installed plant and equipment. Specialist contractors may be required to support some elements of the work including installation of access, temporary equipment, handling of hazardous materials.

31.5.4.3.2 Chemical Decontamination

Upon completion of generation, it is common practice to carry out a chemical decontamination of contaminated fluid systems. The purpose is to reduce general area dose rates and reduce contact dose rates for specific tasks such as thermal insulation removal and, later plant dismantling.

This is often carried out as a two stage process. The first stage uses a chemical process which can remove the internal oxide layer from contaminated pipe systems. The second stage uses a more chemically aggressive process which removes a thin layer of the base metal from treated systems. Ideally this process is performed while the plant remains operable in order to use systems pumps, etc. to drive the process. Temporary skid mounted equipment such as resin beds, heating equipment, etc. can be used depending on the processes planned.

The precise scope of the systems to be included will be assessed during implementation planning but it is assumed that the most potentially contaminated systems such as the Reactor Water Clean-up System (RWCU) and Reactor Pressure Vessel (RPV) will undergo chemical decontamination prior to more aggressive processes. It is expected that the Spent Fuel Storage Pool, the Fuel Pool Cooling and Cleanup System will also be treated in the same way.

31.5.4.3.3 Thermal Insulation Removal

Thermal insulation removal is a non-invasive preparatory task that can be performed during this period. Much of the insulation is expected to be of the clip-on modular type that can be removed simply. The plant will not contain asbestos bearing insulation but there may be areas where Man Made Mineral Fibre is used. This will be removed using industry best practice.

31.5.4.3.4 Alternative Effluent Discharge Line

For the purposes of decommissioning planning, it is assumed that the most appropriate arrangement would be the installation of a new discharge line, installed within the Cooling Water discharge system.

31.5.4.3.5 Characterisation

A targeted campaign of characterisation will be performed in order to update the information used for planning purposes and to reflect the effect of works carried out during this phase. This is also necessary to ensure that there is accurate up to date information regarding the actual radiological status of the plant for more intrusive decommissioning operations.

During this period, spent fuel that has been sufficiently cooled will be transferred from the Spent Fuel Pool to the on-site dry cask Spent Fuel Store. This will be a routine operation throughout this period. After approximately ten years, the final batch of fuel from the reactor will be sufficiently cooled for transfer, after which the Spent Fuel Storage Pools will be empty. Long term records required for on-going storage of the fuel will be prepared and stored.

31.5.4.4 Power Plant Decommissioning

The focus of this period is the dismantling and demolition of the power plant systems and buildings with the intention of leaving the power plant area of the site in the agreed end state. The ILW interim store and the dry cask Spent Fuel Store will not be removed in this phase but will remain for some decades afterwards. At the end of this phase, a smaller footprint site will remain comprising the two store buildings and any associated structures.

31.5.4.4.1 Dismantling and Decontamination

Ideally the plant will be dismantled using the approach of removing all plant and equipment from a room or zone as one operation. This can only be achieved if such rooms or zones are deactivated (i.e. all systems have been shut down and disconnected and are passive). Temporary services will be used to provide lighting and power, etc. This approach helps minimise the risk of attempting to dismantle an in-service / energised system.

Any equipment that is required specifically for dismantling purposes will generally be mobile equipment and will only be installed on a temporary basis as and when it is needed. Dismantling and decontamination works will initially concentrate on the main power island buildings (Reactor Building, Turbine Building, Radwaste Building, etc.) as these are the significant buildings and are expected to represent the critical path through the de-planting project.

One of the earliest major projects in the Reactor Buildings will be de-planting and segmentation of the Reactor Vessel Internals. These are expected to be the highest radiological activity material on site with the exception of the spent fuel. Because of this activity level, they are segmented underwater in-situ and in the Dryer Separator Pool, which will require water and liquid waste management systems to be available. The segmented components are expected to be packaged for disposal in or near the pool. Once the Reactor Vessel Internals are segmented, the water management systems are redundant.

Work in the Turbine Building will also commence early in the de-planting schedule due to the extent of the work required. Work will continue through other radiological buildings and later onto conventional buildings until de-planting is complete. Radiological buildings will be surveyed for contamination of the building structure. Any contamination will be removed using industry standard techniques.

31.5.4.4.2 Construction

It is assumed that there will be an on-going requirement to retrieve spent fuel stored in the dry cask Spent Fuel Store for inspection purposes. In order to satisfy this on-going requirement, a spent fuel "Hot Cell" facility will be constructed on site.

31.5.4.5 Waste Management

A Decommissioning Waste Management Facility (DWMF) will be installed on site, at present it is anticipated that this will be located within the Turbine Building. However, it may be necessary to construct this as a new building. It will be used to monitor and process materials removed from radiological area systems and buildings. These will predominantly be LLW materials (ILW materials from dismantling the reactor itself will be packaged at the work area).

Plant items will be removed from the radiological area in the largest, easiest to handle form practicable, with contaminated materials separated at source from non-contaminated materials where possible. The segregated materials will be surveyed and assigned for release or management as radiological wastes. Radiological waste materials will be sent to the DWMF for further processing which may include decontamination, or dismantling/further segmentation to separate materials into LLW, VLLW and clean categories.

Following processing in the DWMF, wastes arising during this period are managed as during operations, i.e. ILW waste will be packaged for disposal at the GDF and transferred to the on-site ILW interim store to await despatch to the GDF. Long term records will be prepared and stored describing the waste types, characteristics, quantities, treatment processes and route used for all ILW wastes stored in the ILW interim store. LLW, VLLW and non-radiological wastes arising during operation of the site will be transferred to off-site authorised waste processors for management in accordance with the waste hierarchy.

31.5.4.6 Demolition

Following de-planting and decontamination, buildings will be demolished. Building structures above the 1 m below ground level will generally be decontaminated and surveyed such that they can be confirmed radiologically clean and hence demolished using conventional demolition techniques.

It is assumed that below ground structures including building floors greater than 1 m below ground will be left in-situ after survey to confirm that they are free of radioactivity, or can be shown to have radioactivity levels low enough that leaving contamination in place can be justified. Void spaces will be filled either with clean rubble resulting from building demolition or with new material brought to site. Any building rubble not used for void filling or landscaping will be managed off site in accordance with the waste hierarchy.

31.5.5 Remediation and De-licensing

Following completion of the building dismantling works, the power plant site will be surveyed for ground contamination. Any contamination found will be remediated and resurveyed as required performed to demonstrate that the site is free of contamination that it can be released from radiological controls.

The power plant site will then be landscaped as required. Applications will be made to regulators for the power plant area of the site to be de-licensed, leaving only the smaller area occupied by the ILW interim store and Spent Fuel Store (and any associated facilities) as the licensed area.

31.5.5.1 ILW and Spent Fuel Interim Storage Period

At this point the facilities remaining on site consist of:

- ✓ ILW interim store containing packaged ILW wastes
- ✓ Spent Fuel Store containing spent fuel stored in dry casks and the "Hot Cell"

Activities during this period will be limited to care and maintenance activities including maintenance of the buildings, monitoring of the packaged wastes, environmental monitoring and security. Facilities will be provided for retrieval of individual ILW waste packages for inspection purposes. There may also be a requirement to remove spent fuel from a dry cask for inspection purposes using the "Hot Cell" constructed for this purpose. The small quantities of LLW, VLLW and non-radiological wastes arising during operation of the site will be transferred in campaigns to off-site authorised waste processors for management in accordance with the waste hierarchy.

31.5.5.2 ILW Interim Store Emptying

A campaign of removing the packages from the store and transferring them to the GDF will take place, until the store is empty (assumed to take around 5 years). Once emptied, the redundant interim store will be demolished to avoid the need to maintain it during the subsequent spent fuel interim storage period. LLW, VLLW and non-radiological wastes arising during operation of the site and decommissioning of the ILW interim store will be transferred off-site.

31.5.5.3 Spent Fuel Interim Storage Period

This period is provisionally assumed to last for around 140 years from the end of generation of the Unit. At this point the facilities remaining on site consist of the Spent Fuel Store containing spent fuel stored in dry casks, and the "Hot Cell", along with any structures necessary to support them. Activities during this period will be limited to care and maintenance activities including maintenance of the buildings, monitoring of the stored dry casks, environmental monitoring and security. There may also be an infrequent requirement to remove spent fuel from a dry cask for inspection purposes using the "Hot Cell". The small quantities of LLW, VLLW and non-radiological wastes arising during operation of the site will be transferred in campaigns off-site.

31.5.5.4 Spent Fuel Store Emptying and De-licensing of the Site

Before the end of the 140 years' period, work will commence on site on the construction of a Fuel Repackaging Facility (FRF). This facility will be used to remove the stored spent fuel from the dry casks and load it into canisters for transport and disposal at the GDF. At the end of this period the FRF and other remaining structures on site can be de-planted and demolished. The site will then be available for survey and remediation to an agreed end condition. The nuclear site licence and environmental permits associated with the site can then be withdrawn. This marks the end of decommissioning operations.

31.5.6 Further Work Requirements

Within GDA additional work is required to underpin the assumptions and tasks in the decommissioning stages including:

- ✓ Hazards associated with the movement of spent fuel from the SFP and packaging into casks and subsequent transfer to a storage facility, linking to Chapter 32: Spent Fuel Interim Storage. (TR "Decommissioning Assessment")
- ✓ Hazards associated with storage of wastes such as external hazards including extreme weather events and the definition of any relevant environmental conditions within the store needed to support long term storage. (TR "Decommissioning Assessment")
- ✓ A definition of any inspection requirements for both ILW and spent fuel (linking to Chapter 32 Spent Fuel Interim Storage). (TR "Decommissioning Assessment")
- ✓ A demonstration that the currently identified containers are fit for purpose. (TR "Decommissioning Waste Strategy")
- ✓ A demonstration that the spent fuel can be safely stored over an anticipated 140 year period.
- ✓ To produce a decommissioning waste strategy to demonstrate how waste can be packaged for onward management. (TR "Decommissioning Waste Strategy")
- ✓ Underpinned revised decommissioning waste inventory including activation calculations for RPV and reactor internals. This requires input from the ongoing work on source term. (TR "Decommissioning Waste Strategy")
- ✓ A systematic identification of hazards associated with the proposed decommissioning. (TR "Decommissioning Assessment")

31.6 Knowledge Management in the Context of Decommissioning

Safe, efficient decommissioning of the UKABWR can only be achieved on the basis of complete and up-to-date information. Information retention and management need to start during the very early stages of design, construction, commissioning and operation and include modifications. This information needs to be gathered systematically, maintained and remain readable and accessible over the operational life of the reactor and to be made available to inform decommissioning planning. Whilst the management of records (and overall knowledge management) falls under the responsibility of the licensee, there are a number of factors that the licensee will need to consider in defining the relevant management arrangements. However in the early stages of design including the generic design stage it is important to identify those records and knowledge which are important for decommissioning, such information consists of:

- ✓ Design Information throughout the Lifecycle
- ✓ Commissioning and Handover Information
- ✓ Modifications
- ✓ Manufacturing Information
- ✓ Instructions
- ✓ Maintenance Records
- ✓ Radiological Surveys
- ✓ Incident Records
- ✓ Waste, Fuel and Spent Fuel Records
- ✓ Operational Records and Logs
- ✓ Safety Cases and Periodic Reviews of Safety
- ✓ Emergency Plans and Response

Knowledge also rests within the organisation of the licensee and steps should be taken by the licensee to ensure such knowledge is captured and managed through the lifecycle, especially during the transition from operations to decommissioning.

31.7 Assessment of Decommissioning Hazards

A key part of demonstrating that the decommissioning of a UK ABWR can be carried out safely is demonstrating that all reasonably foreseeable faults and hazards have been identified, and that suitable and sufficient safety measures are available to reduce risks to levels that are ALARP. This sub-claim is considered to be justified because:

- ✓ A preliminary review of the hazards associated with decommissioning the UK ABWR indicates that there no novel or unusual hazards associated with the UK ABWR (above those associated with decommissioning other Light Water Reactors).
- ✓ As far as reasonably practicable, the design incorporates features that facilitate decommissioning and allow the process to be carried out safely.
- ✓ Once fuel is removed from the core and the SFP, there will be a ‘step change’ reduction in the hazard presented by the plant.

Each of these arguments is discussed in turn in the subsections below:

31.7.1 High Level Hazards and Faults during Decommissioning

The high level hazards and faults expected during decommissioning have been anticipated and a range of available safety measures and mitigation strategies is identified. These types of hazard are already well known and understood by the UK and worldwide nuclear industry.

Table 31-1: Likely Decommissioning Hazards

Hazard	Discussion	Available Measures
Worker dose	Decommissioning involves processing many high dose items and can involve significant amounts of hands-on work	Material selection to minimise activation (e.g. low cobalt steels) Reactor chemistry to minimise corrosion products (crud) Remote operations (e.g. underwater dismantling)
Spread of contamination	Decommissioning tasks such as equipment dismantling, movement and decontamination can lead to the spread of contamination, and increased doses, both during normal operations and in fault conditions	Installed HVAC from the operations phase Temporary local extract/filtration Local containment Decontamination prior to handling/processing Remote operations (e.g. underwater dismantling) Strippable coatings Personal Protective Equipment (PPE)
Loss of liquid containment (leaks)	System decontamination, flushing and draining can lead to an increased potential for loss of liquid containment	Secondary containment Leak detection Bunding

Dropped Loads	Decommissioning will involve movement of a significant number of large items	Design life of lifting equipment sufficient to support decommissioning Planning of equipment removal routes
Criticality	The export of spent fuel will effectively remove the potential for inadvertent criticality, however during fuel movements the criticality risk may be increased	SFP storage rack Fuel lifting and handling equipment Spent fuel storage cask
Fire	Fire risk can be greater during decommissioning due to the increased presence of combustible materials, use of hot cutting techniques, etc.	Minimisation of ignition sources Use of cold cutting techniques where practicable Minimisation of combustible material/ housekeeping Fire detection and alarm system
Contaminated wounds	Decommissioning can involve an increased amount of hands-on work, leading to an increased risk of contaminated wounds which can lead to high doses	Remote operations where practicable Risk assessment of hands-on operations PPE
Conventional Safety	As decommissioning progresses, and the radiological hazard is progressively removed, conventional hazards will become the principal hazards at the plant	Conventional risk assessment
External Hazards (e.g. seismic, extreme wind, etc.)	The plant is designed to be robust to external hazards during operation. The hazard potential will reduce significantly on shut-down, and again on defueling	No additional measures required to accommodate decommissioning
Internal Hazards (e.g. missiles, explosion, pipe whip/ jet impact, etc.)	Once generation has ceased the potential for many internal hazards is removed (e.g. turbine disintegration, high energy pipework, etc.). The consequence of internal hazards is also much reduced as the number of active safety systems is reduced	No additional measures required to accommodate decommissioning

Further work is required during GDA Step 4 and as part of the site specific safety case to robustly and systematically identify faults and hazards associated with decommissioning.

31.7.2 Design for Decommissioning

The UK ABWR is an evolutionary design, which is based on earlier BWR designs. The UK ABWR design incorporates numerous features that will enable decommissioning to be carried out safely. These features include:

- ✓ Material selection to reduce the amount of highly activated waste, hence reducing worker doses during decommissioning (e.g. low cobalt content steels)
- ✓ Reactor water chemistry control to reduce the amount of corrosion products
- ✓ Optimisation of the design of fluid bearing systems to reduce / avoid low-flow or stagnant areas to reduce the potential for active entrained particulate to deposit.

Design for decommissioning is discussed further in Section 31.3.

31.7.3 Risk Reduction during Decommissioning

Once spent fuel is removed from the core and the SFP, there will be a ‘step change’ reduction in the hazard presented by the plant. This reduction in hazard will reduce the number of faults that are within the design basis and will enable ALARP to be demonstrated for operations during the decommissioning phase.

The nature of the hazards on site will also change, with more manual work carried out under administrative control. Whilst the potential radiological consequences of faults will reduce significantly during decommissioning, the frequency of faults may increase, meaning that the overall risk may still be significant.

The aim of decommissioning is the progressive reduction in radiological risk. However, there may be occasions where a short-term increase in risk is required to achieve longer term risk reduction. For instance, there may be increased risk due to fuel assembly movements in order to remove them from the SFP (e.g. drop/ impact involving a spent fuel assembly). However, this increased risk is required in order to reduce the long term risk associated with storage of spent fuel in the SFP, and allow the SFP to be drained and decommissioned.

As part of decommissioning planning, a Post Shutdown Fault Schedule will need to be developed, taking account of the different operating regime, the reduced hazard and the additional set of initiating faults.

31.8 Review of Operational Experience

31.8.1 UK Experience

Whilst there is no specific experience of decommissioning an ABWR (or BWR) in the UK, there is significant transferable experience of decommissioning of reactors and other nuclear facilities. Such experience includes the following areas:

- ✓ Winfrith Steam Generating Heavy Water (SGHWR) decommissioning (heavy water moderated reactor with similarities to the BWR concept)
- ✓ Nuclear power plant decommissioning at Magnox sites
- ✓ Nuclear facility decommissioning at Sellafield, Dounreay, Harwell and Winfrith sites
- ✓ Reactor dismantling at Windscale Advance Gas-cooled Reactor (WAGR) and research sites

This experience supports the claim that the UK ABWR can be decommissioned using today's technologies. The use of UK experience to refine and define plans for decommissioning will ensure that the specific techniques selected (e.g. underwater cutting of reactor internals) are compliant with UK legislation.

31.8.2 International BWR Experience

No ABWR has yet entered decommissioning, however, numerous earlier designs of BWR variants have been decommissioned or are undergoing decommissioning. For example:

- ✓ Big Rock Point (USA)
- ✓ La Crosse (USA)
- ✓ Hamaoka 1 & 2 (Japan)
- ✓ Gundremmingen A (Germany)
- ✓ Caorso (Italy)

In some cases, the practicability of certain decommissioning tasks has been demonstrated during the operational phase. For instance, some utilities have decided to replace steam dryers (and other items) on their operational plants to address component aging issues or to cope with power uprate programs. Examples include [Ref-15]:

- ✓ Steam Dryers (e.g. Olkiluoto 1, Finland, 2009)
- ✓ Steam Separators (e.g. Olkiluoto 2, Finland, 2004)
- ✓ Core Shroud (e.g. Forsmark 2, Sweden, 2000)
- ✓ Core Shroud Cover (e.g. Oskershamn 2, Sweden, 2003)
- ✓ Core Support Grid (e.g. Forsmark 1, Sweden, 2001)
- ✓ Control Rods (e.g. Forsmark 3, Sweden, 2010)

These items can be some of the most challenging to decommission, and so their successful segmentation and removal supports the claim that the UK ABWR will be able to be decommissioned safely using today's technology.

31.9 Summary of Further Work

Whilst significant progress has been made to date in determining the suitability of the design to aid decommissioning, further work will be required during GDA Step 4. This can be achieved via the Topic Reports which are to be prepared to assist the Step 4 GDA review as outlined here.

- Topic Report – "Decommissioning Strategy"
  - High level strategy defining how decommissioning can be achieved.
- Topic Report – "Design for Decommissioning"
  - A review of how the UKABWR design is optimised for decommissioning including:
    - Access for decommissioning
    - Ability to remove equipment (3D model)
    - Review of embedded pipework and demonstration of decommissioning
    - Leakage of materials
    - Identification of other materials and design features that will assist decommissioning
- Topic Report – "Decommissioning Plan"
  - An overview of how the UKABWR can be decommissioned and the sequence and phasing of such decommissioning.
- Topic Report – "Decommissioning Techniques"
  - An evaluation of decommissioning Techniques used to support the decommissioning of the UKABWR, using existing OPEX and experience.
- Topic Report – "Construction Techniques"
  - A discussion of the benefits of the various construction methodologies, particularly the impact of modular construction on decommissioning
- Topic Report – "Decommissioning Waste Strategy"
  - A strategy for how the decommissioning wastes can be dealt including the long term storage of spent fuel ensuring consistency with Chapter 32: Spent Fuel Interim Storage. Including:
    - Decommissioning Waste Generation
    - Storage
    - Processing/Storage
    - Packaging and Disposal
- Topic Report – "Decommissioning Assessment"
  - A review of the likely hazards that may be encountered during decommissioning including handling and movements of wastes, and how they can be mitigated by the design. Presentation of an ALARP review to ensure dose and waste are minimised in decommissioning.

31.10 Conclusions

Work to date has shown that it is feasible to decommission a UKABWR using existing technology and without the development of novel techniques. It has also been shown that the ABWR design is an evolution from earlier BWR designs which incorporates features which offer substantial benefits to decommissioning processes.

Likely waste streams have been identified with an estimate of quantities. It is however recognised that further work is necessary to demonstrate that all decommissioning wastes generated can be treated and disposed of in accordance with UK requirements.

Further works identified to underpin the claims in the chapter are identified in Section 31.9.

31.11 References

[Ref-1] IAEA, Safety Reports Series 50 "Decommissioning Strategies for Facilities Using Radioactive Material", March 2007

[Ref-2] IAEA, Nuclear Energy Series “Decommissioning of Pools in Nuclear Facilities”, No. NW-T-2.6, Sept. 2015

[Ref-3] Office for Nuclear Regulation, Nuclear safety Technical Assessment Guide – Decommissioning, NS-TAST-GD-026, Rev.3, May 2013

[Ref-4] Environment Agency/Natural Resources Wales, “The Decommissioning of Nuclear Facilities”, Ver.1, Nov. 2013

[Ref-5] Hitachi-GE Nuclear Energy, Ltd., Technical Note “Generic Design Assessment: Summary of Disposability for wastes and Spent Fuel Arising from Operation of the UKABWR”, Livelink no.23383092, Ver.1, June 2015

[Ref-6] Hitachi-GE Nuclear Energy, Ltd., Topic Report on Decommissioning: Section 1 Decommissioning Schedule, GA91-9201-0001-00072 (DCE-GD-0018), Rev.1, Feb. 2015

[Ref-7] Hitachi-GE Nuclear Energy, Ltd., Topic Report on Decommissioning: Section 2 Decommissioning Plan for Main Buildings (R/B, T/B, Rw/B), GA91-9201-0001-00073 (DCE-GD-0024), Rev.0, Dec. 2014

[Ref-8] Hitachi-GE Nuclear Energy, Ltd., Topic Report on Decommissioning: Section 3 Decommissioning Procedure for Typical Equipment, GA91-9201-0001-00074 (DCE-GD-0035), Rev.0, Apr. 2015

[Ref-9] Hitachi-GE Nuclear Energy, Ltd., Topic Report on Decommissioning: Section 4 Applied Technology Evaluation and Section 5 Others, GA91-9201-0001-00075 (DCE-GD-0041), Rev.0, June 2015

[Ref-10] Horizon Nuclear Power Ltd., Preliminary DWMP – Chapter 11, WD03.02-S5-WD-REP-00001, Rev.0.2, Dec. 2014

[Ref-11] Hitachi-GE Nuclear Energy, Ltd., Integrated Waste Strategy, GA91-9201-0003-00425 (WE-GD-0050), Rev.1, May 2015

[Ref-12] Environment Agency, Process and Information Document for Generic Design Assessment of Candidate Nuclear Power Plant Designs, Ver.2, May 2013

[Ref-13] Horizon Nuclear Power Ltd., Horizon Nuclear Power Decommissioning Strategy and Plan, HNP-RL-WD-STR-00003, Rev.4.0, Aug. 2015

[Ref-14] Horizon Nuclear Power Ltd., Selection of Horizon's Decommissioning Strategy - May 2015 Optioneering Exercise, WD03.02.01-S5-WD-REP-00027, Rev.1.0, June 2015

[Ref-15] S Fallstrom, et al (Westinghouse), “A Proven Method for Performing Steam Dryer Segmentation on BWR Plants”, WM2011 Conference (Phoenix AZ), March 2011

31.12 Appendix

Table 31-2: Higher Activity Wastes

Waste Stream (note 1)		Raw Waste Volume/ Mass	Proposed Package Type	No. of Packages
UKABWR01	Condensate Filter Facility (CF) Crud	72.0 m^3	3 m^3 drum	79
UKABWR02	Low Conductivity Waste (LCW) Crud	18.0 m^3	3 m^3 drum	
UKABWR03	Reactor Water Clean-up (CUW) Resin	187.5 m^3	3 m^3 drum	452
UKABWR04	Fuel Pool Clean-up (FPC) resin	84.5 m^3	3 m^3 drum	
UKABWR05	Post-operation Decontamination (DEC) Resin	67 m^3	3 m^3 drum	
UKABWR06	Hafnium (Hf) Control Rods (note 2)	31.65 t	3 m^3 box	17
UKABWR07	Boron Carbide (B4C) Control Rods (note 2)	27.95 t	3 m^3 box	
UKABWR08	Mixed Metal ILW (note 2)	33.0 t	3 m^3 box	4
UKABWR09	Reactor Pressure Vessel internals	374 t	3 m^3 box	126
UKABWR10	Reactor Pressure Vessel	646 t	4 metre box	39

Notes:
1. Streams UKABWR01 to 08 are ‘operational streams’ which will continue to be created during decommissioning. The waste volumes/masses presented are for total arisings (decommissioning and operational life).

2. Some additional cooling may be required for these streams to enable storage/grouting, due to the high decay heat generation currently estimated. This issue is being progressed and this conclusion will be reviewed following update of the source term during GDA Step 4.

Table 31-3: Decommissioning LLW and VLLW (Single Unit)

Category	Waste Group	Source	Pre-treatment	Disposal Route	Waste Package	Total No. of Packages	Disposal total waste volume/Mass (m^3/te)
LLW	**Solid LLW**	Metal (Irradiated & Contaminated)	Cropping, then sort and segregate	LLWR WSC-Metal recycling	WB-1 Waste Box	415	1123te
		Concrete (Irradiated)	Sort and segregate	LLWR-Direct disposal	TC01 HHISO	100	1950m^3
VLLW	**Solid VLLW**	Metal (Irradiated & Contaminated)	Cropping, then sort and segregate	LLWR WSC-Metal recycling	WB-1 Waste Box	1630	4435te
		Concrete (Irradiated & Contaminated)	Sort and segregate	LLWR-Direct disposal	TC01 HHISO	190	3705m^3

Corresponding SSCs : Decommissioning

	Top Claim for Decommissioning						Systems, Structures and Components / System Level safety function		
	Fundamental Safety Function (FSF)		High Level Safety Function (HLSF)		Fault Schedule (Bounding Fault)		Safety Functional Claim (SFC)		
	PCSR Ch.5.4 (List of Safety Category and Class for UK ABWR (AE-GD-0224) 3.2 Identification of ABWR Safety Functions)		PCSR Ch.5.4 (List of Safety Category and Class for UK ABWR (AE-GD-0224) 3.6 Summary of Safety Category and Classification)		- Topic Report on Fault Assessment (UE-GD-0071) Table.4.2-1 Fault Schedule		State	Claim ID	Claim on PCSR Ch.31 (Design Bases)
1	4	Confinement/Containment of radioactive materials	4-7	Functions to confine radioactive materials, shield radiation, and reduce radioactive release	-	-	Normal Operation	Decom-SFC 1	UK ABWR can be decommissioned safely
	4	Confinement/Containment of radioactive materials	4-11	Functions to store the radioactive materials as gaseous wastes	-	-	Normal Operation		
	4	Confinement/Containment of radioactive materials	4-12	Functions to store the radioactive materials as liquid wastes	-	-	Normal Operation		
	4	Confinement/Containment of radioactive materials	4-13	Functions to store the radioactive materials as solid wastes	-	-	Normal Operation		
	5	Others	5-7	Functions to limit the effect of hazard	-	-	Fault		