Form10/00

UK ABWR

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UK ABWR Generic Design Assessment

Demonstration of BAT

Hitachi-GE Nuclear Energy, Ltd.

Form10/00

UK ABWR

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<u>*Table of Contents*</u>

1. Acronyms

ABWR	Advanced Boiling Water Reactor
AC	Atmospheric Control System
ALARA	As Low As Reasonably Achievable
ALARP	As Low As Reasonably Practicable
BAT	Best Available Technique
BPEO	Best Practicable Environmental Option
BPM	Best Practicable Means
Bq	Becquerel
BSS	Basis Safety Standards Directive
BWR	Boiling Water Reactor
C&I	Control and Instrumentation
CAD	Controlled Area Drain
CCI	Commercially Confidential Information
CD	Condensate Demineraliser
CDL	Calculated Detection Limit
CF	Condensate Filter
COMAH	Control of Major Accident Hazards
CONW	Concentrated Waste System
CP	Corrosion Product
CSG	Combustion Sector Guidance Note
CST	Condensate Storage Tank
CUW	Reactor Water Clean-up System
CW	Circulating Water System
CWP	Circulating Water Pump
D/W	Dry well
DAW	Dry Active Waste
DCD	Design Control Document
DECC	Department of Energy and Climate Change
DEFRA	Department for Environment, Food and Rural Affairs
DF	Decontamination Factor
DORIS	The marine dispersion model used in PC-CREAM 08®
DPUR	Dose Per Unit Release

EIA	Environmental Impact Assessment
EMCLs	Environmental media concentration limits
EPR/EPR10	Environmental Permitting (England and Wales) Regulations 2010
EQS	Environment Quality Standards
ERICA	Environmental Risk from Ionising Contaminants: Assessment and Management
ESE	Environmentally Sensitive Equipment
EU	European Union
f-value	Fuel leakage rate
F/D	Filter-Demineraliser
FAP	Forward Action Plan
FDP	Funded Decommissioning Programme
FDW	Feedwater System
FP	Fission Product
FPC	Fuel Pool Cooling and Clean-up System
GDA	Generic Design Assessment
GDF	Geological Disposal Facility
GEP	Generic Environmental Permit
GNF	Global Nuclear Fuel
GSD	Generic Site Description
HAW	Higher Activity Waste
HCEP	How to comply with your environmental permit
HCW	High Conductivity Waste System
HEPA	High Efficiency Particulate Air (Filter)
HFE	Human Factors Engineering
HFF	Hollow Fibre Filter
HLW	High Level Waste
HNCW	HVAC Normal Cooling Water System
HOP	Hydrazine, Oxalic acid, Potassium permanganate
HS	Heating Steam System
HSCR	Heating Steam and Condensate Water Return System
HSD	Hot Shower Drain
HSE	Health and Safety Executive (UK)
HVAC	Heating Ventilation and Air Conditioning System
HWC	Hydrogen Water Chemistry
I&C	Instrumentation and Control

IA	Instrument Air System
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
IEX	Ion-exchange (demineraliser) system
ILW	Intermediate Level Waste
IPPC	Integrated Pollution Prevention and Control
IRA	Initial Radiological Assessment
IWS	Integrated Waste Strategy
KK-6	Kashiwazaki-Kariwa Nuclear Power Station Unit 6
KK-7	Kashiwazaki-Kariwa Nuclear Power Station Unit 7
LCW	Low Conductivity Waste System
LD	Laundry Drain System
LLW	Low Level Waste
LLWR	Low Level Waste Repository
LoC	Letter of Compliance
LOCA	Loss of Coolant Accident
LPRM	Local Power Range Neutron Monitor
LS	Laundry System
LWR	Light Water Reactor
MCERTS	Monitoring Certification Scheme
MS	Main Steam System
NDA	Nuclear Decommissioning Authority
NHS	Non Human Species
NMCA	Noble Metal Chemical Addition
NPP	Nuclear Power Plant
NRW	Natural Resources Wales
NUREG	Nuclear Regulatory Commission Regulation (US)
Off-Gas	Off-gas
ONR	Office for Nuclear Regulation
OSPAR	Oslo and Paris Convention on Protection of the Marine Environment of the North East Atlantic
P&D	Plumbing and Drainage System
P&ID	Process and Information Document for Generic Assessment of Candidate Nuclear Power Plant Design
P/C	Power Centre
PCI	Pellet Cladding Interaction

PCSR	Pre-Construction Safety Report
PI	Personal Information
ppb	parts per billion
PWR	Pressurised Water Reactor
QA	Quality Assurance
QAP	Quality Assurance Plan
QC	Quality Control
QMP	Quality Management Plan
QMS	Quality Management System
R/B	Reactor Building
RCLEA	Radioactively Contaminated Land Exposure Assessment
RCW	Reactor Building Cooling Water System
REP	Radioactive Substances Regulation – Environmental Principle
RGP	Relevant Good Practice
RP	Requesting Party
RPDP	Radiation Protection Developed Principle
RQ	Risk Quotient
RSA	Radioactive Substances Act
RSR	Radioactive Substances Regulation
RSW	Reactor Building Service Water System
RW/B	Radwaste Building
RWMA	Radioactive Waste Management Arrangement
RWMD	Radioactive Waste Management Directorate
S/B	Service Building
S/P	Suppression Pool
SA	Station Service Air System
SAM	Sampling System
SAP	Safety Assessment Principle
SCC	Stress corrosion cracking
SF	Spent Fuel
SFAIRP	So far as is reasonably practicable
SFP	Spent Fuel Pool
SGTS	Standby Gas Treatment System
SJAE	Steam Jet Air Ejector
SLC	Standby Liquid Control System

SoDA	Statement of Design Acceptability
SPCU	Suppression Pool Clean-up System
SQEP	Suitably Qualified and Experienced Person (UK)
SRNM	Start-up Range Neutron Monitor
SS	Spent Sludge System
Sv	Sievert
T/B	Turbine Building
TIP	Traversing In-core Probe
TCW	Turbine Building Cooling Water System
TSW	Turbine Building Service Water System
TV	Tank Vent Treatment System
UF	Uncertainty Factor
UK	United Kingdom
US	United States
VLLW	Very Low Level Waste
WENRA	Western European Nuclear Regulators' Association

2. References

1 Process and Information Document for the Generic Assessment of Candidate Nuclear Power Plant Designs, version 2, Environment Agency, March 2013.

2 How to comply with your environmental permit for radioactive substances on a nuclear licensed site, GEHO0812BUSS-E-E, 478_10, Version 2, Environment Agency, 21 August 2012.

3 Approach to Optimisation, GA91-9901-0021-00001, XE-GD-0096, Rev C, Hitachi-GE, March 2014.

4 Radioactive Substances Regulation - Environmental Principles, version 2, Environment Agency, April 2010.

5 RSR: Principles of optimisation in the management and disposal of radioactive waste, Issue 2, April 2010, Environment Agency.

6 Consideration of and Compliance with the Radioactive Substances Regulation Environmental Principles (REPs), GA91-9901-0028-00001, XE-GD-0099, Rev C, Hitachi-GE, March 2014.

7 Radioactive Waste Management Arrangements, GA91-9901-0022-00001, WE-GD-0001, Rev C, Hitachi-GE, March 2014

3. Introduction

This report presents the Claims and Arguments that have been developed to demonstrate the application of Best Available Technique (BAT) to the UK ABWR. In doing so, it is demonstrated that the environmental performance associated with the practice of generating electricity from the UK ABWR will be optimised, and that impacts from potentially harmful ionising radiation on members of the public and the environment will be minimised.

This report forms part of Hitachi-GE's Generic Design Assessment (GDA) submission for the Environment Agency's initial assessment. The Environment Agency's requirements for undertaking environmental optimisation of discharges of radioactivity and to demonstrate the application of BAT for the GDA submission are defined within the Environment Agency's Process and Information Document (P&ID) (1).

These requirements are consistent with the Environment Agency's standard permit conditions (2) that would apply to any future operator of a UK ABWR. To ensure the content and assessment of the Generic Environmental Permit application is consistent with future site specific permit applications, Hitachi-GE has elected to focus on the standard permit conditions that relate to BAT. These conditions have been used to form the Claims that are a key part of the approach adopted in GDA to demonstrate the application of BAT. This approach is described in full in the 'Approach to Optimisation' report (3) (also submitted for the Environment Agency's initial assessment) and uses the Claim-Argument-Evidence approach. These two reports should be read in conjunction to give the fullest indication of Hitachi-GE's approach and understanding of the derivation of the Claims and Arguments made in this report.

The substantiation of the Arguments presented at this initial stage of the GDA process will be provided as part of the Step 2 GDA submission in the form of supporting Evidence.

4. Approach to Environmental Optimisation and the Application of Best Available Techniques

4.1. Regulatory Environmental Principles

In the 'Approach to Optimisation' report (2) Hitachi-GE has developed a methodology that sets out the approach to environmental optimisation and the application of BAT being implemented for the UK ABWR. This methodology is considered to be consistent with industry relevant good practice (RGP) and takes into account the relevant Radioactive Substances Regulation Environmental Principles (REPs) (4) and principles of optimisation set out in the guidance document 'RSR: Principles of optimisation in the management and disposal of radioactive waste' (5).

Hitachi-GE's 'Consideration of and Compliance with the REPs' report (6) details the approach undertaken by Hitachi-GE to review and incorporate each of the relevant REPs within the GDA submission, highlighting the REPs specifically taken into account in each report. Each Claim made within this report, highlights the key REPs that it addresses.

A summary of the regulatory context that defines the requirement for environmental optimisation and the application of BAT is also provided within the 'Approach to Optimisation' report (3).

4.2. Hitachi-GE BAT philosophy

In the case of demonstrating BAT, the objective of Hitachi-GE's approach to environmental optimisation is to deliver the following objectives:

- Protect members of the public from exposure to potentially harmful ionising radiation and reduce any doses to As Low as Reasonably Achievable (ALARA);
- Protect the environment within which we operate and live;
- Enable the nuclear power station to operate efficiently;
- Enhance reputation as a 'good neighbour'; and
- Comply with regulations (as summarised in Hitachi-GE's 'Approach to Optimisation' (3).

Hitachi-GE's approach is guided by the following principles:

- **Evolution of the UK ABWR design**: Boiling water reactors benefit from a long operational history, which has enabled operational feedback to inform the design. Safety, environment and operability have all influenced how the design has evolved at each design iteration. Through the application of this methodology Hitachi-GE will demonstrate how the design has evolved resulting in very low discharges to the environment.
- **Integration of the BAT methodology into decision making**: There are several considerations that need to be borne in mind when making decisions on the design and future operation of a nuclear power station. Some of these are directly attributed to the ONR requirements, for example, the reduction of worker dose to ALARA, whereas others are less specific, such as 'trouble' (e.g. ease of implementation, operability and decommissioning implications) or 'technology maturity'. Importantly – the demonstration of BAT needs to be integrated into the project programme and decision making process.
- **Opportunity:** Recognising that the demonstration of BAT should cover the lifecycle of the plant, certain elements will be best addressed during GDA whereas others will be better managed at a

site-specific level. In conjunction with future operators, Hitachi-GE have endeavoured to identify the best time to deliver elements of the programme to ensure that opportunities to further optimise the UK ABWR can be realised.

The key steps of the BAT methodology adopted by Hitachi-GE are summarised within Figure 4.2-1 below. For a full description, see 'Approach to Optimisation' (3).

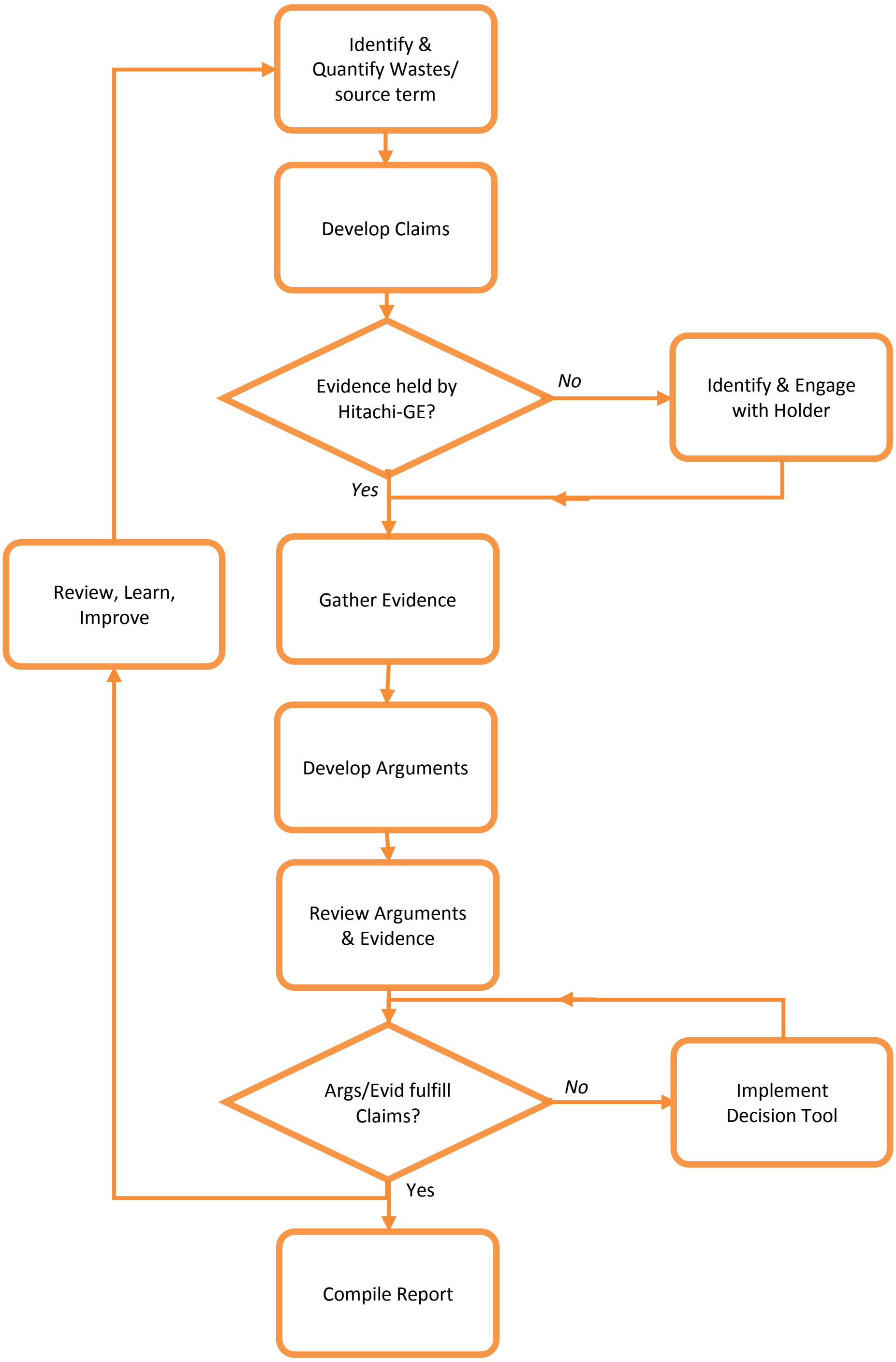

Figure 4.2-1: Methodology for Demonstrating the Application of BAT

4.3. Context of Optimisation within the GDA process

The demonstration of environmental optimisation and the application of BAT for the UK ABWR will take place across all stages of the project life cycle (from design through to decommissioning). The approach to environmental optimisation adopted by Hitachi-GE as set out in the 'Approach to Optimisation' (3) provides a framework that supports both the evolution that takes place as a design develops and the iterative nature of any BAT demonstration. This ensures that opportunities are both explored and realised during the phase of the project life cycle where they are expected to deliver the greatest benefit. The environmental optimisation of the UK ABWR is therefore focused on two key themes:

- **Engineered systems and controls -** The design of engineering systems and controls that contribute to the prevention of radioactive wastes and discharges and that minimise the impact of any discharges on members of the public and the environment; and,
- **Management systems and controls -**The operation of the engineered systems and controls will be further optimised through the development and implementation of management systems and controls.

At the GDA stage it is considered important to demonstrate the application of BAT in relation to those features of the design that could foreclose options at later stages of the project's life cycle. This will include, for example, specific decisions that a future operator may wish to take. This 'Demonstration of BAT' report will therefore focus on engineered systems and controls. Where the design will be influenced by site-specific factors, consideration of how to prevent the foreclosure of options by providing flexibility within the design will be set out within the supporting Evidence. Whilst it is recognised that the management system and controls will be developed during the site-specific assessment the following considerations will be made during the Evidence gathering process of the GDA:

- How engineered systems and controls contribute to the effectiveness of management systems and controls and vice versa; and,
- How Human Factors Engineering (HFE) is taken into account, to ensure that management systems and controls can be effectively implemented.

5. Claims and Arguments

This section sets out the Claims and Arguments developed for the UK ABWR through application of the methodology outlined in full in the ‘Approach to Optimisation’ (3).

In summary, for the demonstration of BAT in GDA, Hitachi-GE defines a Claim as:

- A clear statement of what will be achieved; and
- A demonstration of compliance with the requirements of the P&ID and those conditions in the generic permit that are subject to the application of BAT.

Arguments are presented to demonstrate that a Claim is valid. A Claim is further developed by:

- Identifying those aspects of a design that contribute to the generation of radioactive waste;
- Establishing waste streams and arisings;
- Determining those environmental permit conditions that require environmental optimisation to apply; and
- Understanding what is required to demonstrate compliance with relevant permit conditions.

Figure 5-1 presents the Claim–Argument-Evidence structure that is to demonstrate the application of BAT for the UK ABWR. This figure illustrates how the Evidence that will be presented at Step 2 will be used to substantiate the Arguments presented within this report.

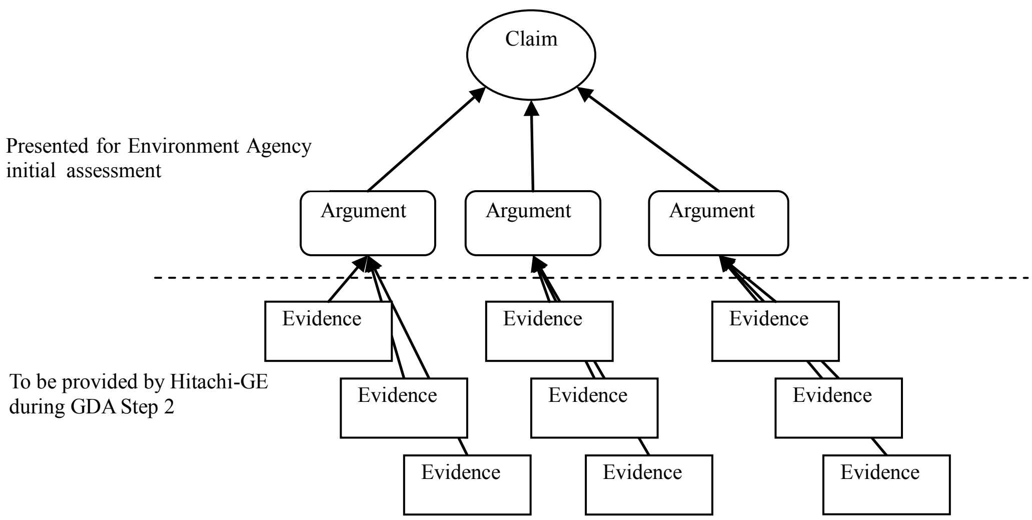

Figure 5-1: Claim-Argument-Evidence structure

5.1. Claim 1: Eliminate or Reduce the Generation of Radioactive Waste

The creation of radioactive waste during the operation of the UK ABWR is undesirable due to the potentially harmful effects of exposure to members of the public and the environment and the time, trouble and cost incurred in its management. The evolution of the UK ABWR design has sought to avoid the generation of radioactive waste at source. Where this has not been practicable, efforts have been made to minimise the activity and quantity of radioactive waste that will require subsequent management and disposal by permitted means.

The Arguments presented in support of this Claim are considered to demonstrate compliance with the standard BAT conditions (2) and the relevant requirements of the P&ID (1) as listed below:

- Condition 2.3.1 'The operator shall use the best available techniques to minimise the activity of radioactive waste produced on the premises that will require to be disposed of on or from the premises.'

This is also considered to fulfil the following requirement of the P&ID:

- Preventing and minimising (in terms of radioactivity) the creation of radioactive waste.

The UK ABWR design contains a range of features that contribute to the substantiation of this Claim including:

- Design, manufacture and manage nuclear fuel to minimise the potential for a release of fission products from the fuel into the steam circuit or cooling pool water;
- Elimination or reduction of materials that are susceptible to activation at all stages of commissioning and operation;
- Reduce the generation of spent nuclear fuel and Higher Activity Waste (HAW) for a given energy output;
- Reduce the generation of Lower Activity Waste (LAW) for a given energy output;
- Prompt detection and management of failed fuel; and
- Introduction of techniques to be used during commissioning, start-up and shut down to minimise the incidence of stress corrosion cracking (SCC) of key reactor components.

In developing the Arguments presented to demonstrate the validity of Claim 1 the REPs have been taken into account, with the following REPs considered specifically relevant:

- **Principle RSMDP3** ‘the best available techniques should be used to ensure that production of radioactive waste is prevented and where that is not practicable minimised with regard to activity and quantity.’
- **Principle ENDP1** ‘The underpinning environmental aim for any facility should be that the design inherently protects people and the environment, consistent with the operational purpose of the facility.’
- **Principle CLDP1** ‘The best available techniques should be used to prevent and where that is not practicable minimise radioactive contamination of land and groundwater, whilst allowing permitted disposals of radioactive waste.’

5.1.1. Argument 1a: Design, Manufacture and Management of Fuel

The fuel is the largest source of radionuclides that are created as a result of nuclear fission in the reactor. Collectively these radionuclides are referred to as 'fission products'. Any release of fission products from the fuel into the steam circuit or cooling pool water have the potential to become radioactive waste that will ultimately require treatment and/or discharge to the environment. Consequently, ensuring that these fission products remain within the fuel and its associated cladding is a key element of the design and operation of the UK ABWR.

Fuel failures are typically small cracks in the fuel cladding which allow fission products to be released into the steam circuit from the fuel pellets themselves. The manufacturer of the fuel for the UK ABWR, Global Nuclear Fuels (GNF), is engaged in a long-standing and comprehensive programme of work to improve the performance of its products and to reduce the frequency of fuel failures. Developments include:

- Introduction of advanced filters within the fuel assembly to remove debris that can damage the fuel;
- Introduction of a pure zirconium liner to reduce SCC due to the pellet-cladding interaction (PCI); and,
- Thermal margin improvement by extending the fuel rod array.

These improvements have been accompanied by empirically established guidelines to the users of GNF's fuel which clearly defines the operating parameters of the fuel and the means by which fuel failures can be mitigated during operation.

GNF collaborates closely with its customers to monitor the performance of its fuel and to understand the mechanisms that give rise to fuel failures. Comprehensive data are available on the performance of its fuel in reactors in Japan, the United States of America and Europe. Analysis of these data has been undertaken by GNF and concludes that GNF's improvement programme has significantly improved the reliability and performance of GNF fuel in Light Water Reactors. The data gathered from operational experience is fed back into the GNF fuel programme and is used to support the development of future enhancements.

GNF's fuel cladding is manufactured from a zirconium alloy. This material is widely used in the nuclear industry and has been selected because it is transparent to neutrons, resistant to corrosion and is impermeable to the migration of fission products from the fuel into the steam circuit.

Any uranium on the external surfaces of the fuel has the potential to undergo nuclear fission and to generate fission products that will enter the steam circuit. This material is referred to as 'tramp uranium'. GNF has quality assurance processes in place that minimise the potential for the external surfaces of its fuel to become contaminated with uranium during manufacturing processes.

Hitachi-GE has developed fuel handling equipment that minimises the potential for damage during transportation, loading, unloading and storage of fuel and spent fuel. Operational experience and feedback from the operating fleet of BWRs in Japan, United States of America and Europe has shown that there is an extremely low frequency of fuel damage associated with management of fuel and spent fuel outside of the reactor.

Collectively these measures will ensure that the transfer of fission products from the fuel to the steam circuit and the cooling pool water will be minimised and that BAT is being applied to the design, manufacture and management of nuclear fuel. This, in turn, will minimise the quantity of secondary waste that is generated from the management and treatment of fission products in the gaseous and aqueous effluents.

5.1.2. Argument 1b: Reactivity Control

Fluids and materials that pass through the reactor core are exposed to an intense field of neutrons generated from nuclear fission. Interactions with neutrons in some instances result in the generation of activation products which require treatment and/or disposal as radioactive waste. The elimination or reduction of materials that are susceptible to activation is important to the minimisation of radioactive waste produced in the UK ABWR.

The UK ABWR uses a physical method known as ‘recirculation flow control’ for controlling the rate of the nuclear reaction (reactivity) in the core. The ratio of water to steam is managed by controlling the recirculation flow rate in the core. The water acts as a neutron moderator and increases the rate of fission. Put simply, the greater the ratio of water to steam in the reactor core, the higher the reactivity will be and vice versa. The UK ABWR also uses burnable gadolinium rods for reactivity control. The use of the recirculation flow control method, gadolinium rods and control rods eliminates any need for chemical agents to control the reactivity. Conversely, in pressurised water reactors (PWR), chemical agents such as boron are used to control reactivity and are a significant source of the tritium that is discharged to the environment. There are no large-scale economic systems for the treatment of tritium and global practice across the nuclear industry is that tritium is disposed of to the environment. Discharge data in Japan shows that the amount of tritium disposed of to the environment from (A)BWRs is lower than PWRs.

Control rods are used to absorb neutrons and reduce the reactivity in part of or the entire reactor core. Conventional types of control rods contain boron carbide (B_4C) whilst more recent designs contain hafnium. The UK ABWR is likely to use both B_4C control rods and hafnium control rods in its reactor. Hafnium control rods, which have a longer operational life, are used not only for shutdown but for reactivity control during normal operation, which results in their higher exposure. B_4C control rods are normally used only for shutdown. Hence, hafnium control rods reduce the quantity of waste generated from the less frequent replacement and management of control rods at the end of their service life.

5.1.3. Argument 1c: Efficiency of Fuel Use

The efficiency with which the nuclear fuel is used in the UK ABWR, and the frequency with which it is changed, will influence the amount of spent fuel and higher activity waste that is generated during operations. Reducing the generation of spent fuel and higher activity waste for a given energy output is an important part of optimising the nuclear fuel cycle from an environmental perspective. This applies to the selection of the nuclear fuel and the final choice for its management prior to disposal. The design of the UK ABWR will prevent the unnecessary generation of waste and discharges associated with its management by ensuring that the minimum quantity of spent nuclear fuel is produced per unit of electricity generated.

The UK ABWR's reactor core is arranged as an upright cylinder and contains a large number of fuel assemblies. The design of the core has evolved over many years of BWR operation. Compared to a PWR, BWR has a smaller power density, larger fuel inventory, more fuel bundles, and smaller ratio of fuel assembly exchange. The flexibility of the fuel loading pattern allows fresh fuel to be placed at the core interior and old fuel to be placed at the core periphery. In addition, each fuel rod has axial enrichment distribution with lower enrichment at both top and bottom end. These BWR characteristics lead to increased fuel efficiency due to a decrease in neutron leakage. In addition, BWR employs ’spectral shift operation’ for enhanced fuel burn-up. In the BWR, the fuel with high void fraction has a high energy neutron spectrum, therefore more plutonium is produced in the fuel. This effect increases in proportion relative to the period of the burn-up with high void fraction. The BWR core is therefore operated at the high void fraction, from the start to the middle of the operation cycle, so that plutonium production is promoted. Toward the end of the operation cycle, the core is operated at the low void fraction so that plutonium is consumed and rated power capability extended. In this way, the reactivity of the plutonium that is generated improves fuel cycle efficiency.

Typically the first shutdown for refuelling will take place up to 13 months after the start of initial power operations. Thereafter, the cycle length can be varied up to 18 months using GE14 fuel (GE14 fuel comprises 10x10 array of fuel rods, two water rods, spacers, a lower tie plate, an upper tie plate and a channel box) with further potential to achieve 24 month cycles. The desired fuel cycle length is achieved by optimising the refuelling batch size and the average enrichment of the fuel bundles. Operational experience has demonstrated the length of each fuel cycle using GE14 fuel. Additionally, advances in fuel technology have consistently provided reductions in fuel requirements for the BWR such that GE14 batch sizes presented here can be considered conservative when evaluating fuel efficiency over the life of the plant.

5.1.4. Argument 1d: Detection and Management of Failed Fuel

The GE14 nuclear fuel that will be used in the UK ABWR is designed, manufactured and managed to minimise the potential for fuel failures that could subsequently result in the release of fission products into the steam circuit (5.1.1: Argument 1a: Design, Manufacture and Management of Fuel). In the unlikely event that a fuel failure occurs and fission products enter the steam circuit, the ABWR has a range of features that allow for prompt detection and management (refer to 5.2.2: Argument 2b: Off-Gas Charcoal Adsorber for Noble Gases and Iodine).

The concentration of fission products in the gases entering the gaseous waste treatment system from the steam condenser is continuously measured by dedicated instruments which are connected to the UK ABWR's control system.

The design of the UK ABWR reactor core allows the operator to locate the source of the failed fuel by the selective insertion of control rods around fuel assemblies. Insertion of the control rods suppresses nuclear fission in immediately adjacent fuel assemblies and allows the operator monitoring the concentration of fission products in gases from the condensers to detect the source of the leak. This process of detecting a failed fuel assembly is referred to as power suppression testing.

The design of the UK ABWR allows a graduated response to be taken to a fuel failure in the reactor. Operational experience and feedback from the BWR fleet in Japan, the United States of America and Europe demonstrates that the flexible design of the UK ABWR is capable of providing a range of responses that take account of the severity of the fuel failure and reflect local operating and regulatory requirements.

5.1.5. Argument 1e: Commissioning, Start-Up and Shut Down Procedures

Start-up and shutdown of the reactor has the potential to generate radioactive wastes as a result of the:

- Increase of the generation of corrosion products containing materials that are susceptible to activation as they deposit on the fuel in the reactor core; and
- Increase in the incidence of stress corrosion cracking of key reactor components that will subsequently require replacement.

There are a number of techniques that have been developed for use during commissioning, start-up and shutdown of the plant that collectively reduce the generation of radioactive waste during each operating cycle. These techniques have been successfully deployed on the (A)BWR reactor fleet in Japan.

Experience of operating BWRs in Japan has shown that the deposition of Cobalt-60 in the oxide film that accumulates on pipe and vessel internals is a significant contributor to worker dose during an outage. Prior to or during commissioning, some pipes and vessels undergo processes to create a film of oxide on internal surfaces. This contributes to a reduction in doses from pipes in the Reactor Water Clean-Up Unit (RWCU) of approximately 80%. A negative consequence of the action is that Cobalt-59 ions that do not accumulate on pipe and vessel internals have the potential to become activated as they pass through the reactor core, which would result in a very small increase of the radioactivity in the waste. Given that such activation products would accumulate on the demineraliser resins it is considered that the benefit from dose reductions outweighs the detriment associated with a small increase of radioactivity in the demineraliser resins.

Oxide films are removed during chemical decontamination processes. Historically this has meant that the benefits of pre-coating pipes and vessels with oxide films are only available prior to the first decontamination operation.

An alternative process, called Hi-F Coat, which forms a magnetite film on the surface of stainless steel piping is applied just after the decontamination by the Hydrazine, Oxalic Acid, Potassium Permanganate (HOP) method, which is described below. This technique has been developed and has been successfully applied to BWRs in Japan. The technique to apply the Hi-F method to carbon steel is now under development.

Ferrous materials present in the steam circuit after installation, maintenance or decontamination operations have the potential to pass through the reactor core and become activated. Plant start up arrangements include re-circulating condensate and feed water through their respective clean-up systems prior to bringing the reactor back into service. This allows any residual material in the condensate and feed water systems to be captured in filters and minimises the potential to generate Manganese-54 and Iron-59 from the activation of ferrous materials, which would subsequently require treatment as radioactive waste.

Enhancements have been made to shutdown techniques by the adoption of Low Temperature Residual Heat Removal Shutdown Cooling. This accelerates the cooling process and reduces the amount of radioactivity deposited on the internal surfaces of pipes and vessels by approximately 80%. The main benefit of this technique is that doses to workers are reduced during outage activities. Once the plant has been fully shut down, the condition of the water that remains in the pipes and vessels is carefully managed. This has the effect of further minimising the generation of corrosion products and extending the service life of the demineraliser resins.

Chemical decontamination is routinely used to remove radioactivity from the internal surfaces of pipes and vessels. The UK ABWR will use the HOP method developed by Hitachi-GE. This has been demonstrated in service to deliver decontamination factors of between 10 and 80, with a commensurate reduction in average dose rate of approximately 95%. Compared with other techniques the chemicals used in the process are decomposed completely and the wastes that are generated can be processed through the plant's existing waste treatment systems. This minimises the quantity of secondary waste generated from decontamination processes.

5.1.6. Argument 1f: Water Chemistry

The fundamental function of the water coolant in the UK ABWR's steam circuit is to transfer heat from the fuels and to generate the steam necessary to drive the turbines. The chemistry of the coolant is carefully managed to deliver the following effects:

- Reducing occupational exposure to radiation for workers;
- Reducing failures of the fuel cladding associated with corrosion;
- Minimising generation of corrosion products that could become activated in the reactor core; and,
- Minimising the replacement of reactor and process components associated with material corrosion.

Management of the water chemistry has been a fundamental element of the work undertaken by

Hitachi-GE to reduce the failure of fuel, to reduce operator dose and to improve plant availability. Data available for BWRs show that by the early 1990s the number of fuel failures had reduced to approximately 10% of the peak experienced in 1974 and that occupational exposure had reduced to less than 20% of that experienced in 1978. Availability of the plant continued to show an upward trend during this period.

Progressive improvements have been made to the water coolant purification system including the provision of a condensate clean-up system and a reactor clean-up system. These systems make a significant contribution to preventing any corrosion products generated in the turbine system from entering the reactor. This reduces the generation of activation products Iron-59 and Manganese-54 which require subsequent treatment as radioactive waste. In combination with the Oxygen injection and the selection of corrosion resistant materials, the concentration of Iron cruds in the feedwater entering the reactor has been reduced from 7.5-15 parts per billion (ppb) to 0.02 ppb.

Diverse materials are used throughout the steam circuit in the UK ABWR which means that it is not possible to develop an approach to water chemistry that has a universal effect. Water chemistry in the the UK ABWR is optimised taking into account the material properties and operating conditions. Iron injection is provided to stabilise the oxide of Nickel and Cobalt on the surface of the fuel cladding, which results in lower concentrations of radioactive Cobalt in the reactor water. The physical method of injecting iron has been improved in order to eliminate the injection line blockages that were experienced using electrolysis iron injection. The method to be adopted in the UK ABWR uses a Condensate Filter (CF) bypass which is a standard method to control iron concentration in feed water, underpinned by operational experience of its benefits from ABWR plants in Japan. In addition, Zinc injection is used to introduce ions that compete with cobalt ions for deposition sites on the internal surfaces of pipes and vessels. By reducing the potential for Cobalt-60 to deposit, the associated occupational exposure to workers during maintenance activities is reduced. There is a disbenefit in that Cobalt-59 that does deposit on surfaces may become irradiated in the reactor core and will require treatment as radioactive waste. The significant benefits associated with the reduction of occupational exposure are considered to outweigh the disbenefits from the additional generation of radioactive waste.

Early generations of the BWR were highly susceptible to stress corrosion cracking. Repairs to reactor components and associated plant resulted in generating significant quantities of radioactive waste, increasing occupational exposures to workers and reducing the availability of the plant. To combat this, Hydrogen Water Chemistry (HWC) systems have been used in BWRs since the early 1980s mitigating the impact of the corrosive environment created by the radiolysis of the cooling water in the reactor. The addition of hydrogen in the feedwater has the combined effect of reducing concentration of dissolved oxidants and reducing the electro-chemical corrosion potential of the pipes and components. A side effect of HWC is that the rate of transfer of Nitrogen-16 to the steam created in the reactor increases by a factor of 4-5 times with a commensurate increase in dose rate. Since the mid-1990s HWC has been augmented by Noble Metal Chemical Addition (NMCA) in the United States which delivers a large reduction in the electro-chemical potential with a relatively low level of hydrogen addition. This has contributed to a reduction in the quantity of Nitrogen-16 in the main steam whilst continuing to offer protection against stress corrosion cracking.

Operational experience and feedback has demonstrated that the water chemistry of ancillary systems, such as the fuel pool and suppression pool, is neutral and as such does not require further treatment. The water temperature of these systems is low, therefore no further controls are required to prevent evaporation or to protect against corrosion.

5.1.7. Argument 1g: Specification of Materials

Materials in the reactor are exposed to neutrons generated by nuclear fission. In some instances the materials will become radioactive by a process known as 'activation'. These 'activation products' are a significant source of radiation doses to workers and of radioactive waste. There are two main sources of activation products:

- Structural materials within the reactor that are activated by their proximity to nuclear fuel and the associated neutron flux. These materials become radioactive waste during maintenance and decommissioning tasks;
- Corrosion products that are suspended in the reactor water deposit on the surface of the fuel cladding as a result of boiling densification and become activated. The activated elements can then be re-dissolved into the reactor water and subsequently have the potential to contribute to an increase in dose.

The UK ABWR takes account of decades of experience in the design, operation and decommissioning of Light Water Reactors (LWR) and, where practicable, uses materials that are less susceptible to corrosion, deposition and activation. Efforts to use alternative materials have sought to balance the benefits provided by the characteristics of the materials with their safety and environmental implications.

Cobalt is present in the stainless steels and nickel based alloys that are used within the UK ABWR's reactor and parts of the steam circuit. Cobalt is also a significant component of cobalt based alloys (Stellite®) that have been historically used in reactor systems due to their corrosion resistance and hard-wearing properties. The naturally occurring isotope Cobalt-59 becomes activated by neutrons to create the radioactive isotope Cobalt-60. Progressive evolutions of the BWR design have sought to reduce the amount of cobalt present in materials of construction. The design of the UK ABWR now includes the specification of low cobalt steels for a range of components that are particularly susceptible to activation or corrosion with subsequent activation. The design also limits the use of Stellite® alloys to only those components where Stellite® is essential for material performance. In combination, these improvements have resulted in an approximately 50% reduction in the amount of Cobalt-60 generated during operations of the ABWR.

Corrosion products generated in the condensate system have been reduced by the progressive introduction of corrosion resistant steels over several evolutions of the (A)BWR design. The corrosion products contain the naturally occurring isotopes Iron-56 or Iron-58 which, when activated, become Iron-59 or Manganese-54. The improvements have contributed to reducing the concentration of iron in the feedwater from between 7.5-15 parts per billion (ppb) to 0.02 ppb in the ABWR.

5.1.8. Argument 1h: Recycling of Water within Steam Circuit

Water is used as the coolant within the UK ABWR and to generate the steam that is used in the turbines to generate electricity. The water coolant becomes radioactive as it passes through the reactor and around the steam circuit. High concentrations of radioactivity in the steam circuit are undesirable as it can result in increased operational exposure to workers during operational and maintenance activities. The disposal of the contaminated water is also undesirable as it could harm members of the public and the environment.

The design of the UK ABWR includes the following systems for recycling water used during operations and maintenance:

- The Condensate Water Clean-Up System treats condensed water that has passed through the turbines and been condensed back to water. Filters remove any solid matter that could either damage the fuel or become activated in the reactor core. Demineralisers are used to remove ions that have become activated or have the potential to become activated in the reactor core or deposit on internal surfaces of pipes and vessels.
- The Reactor Water Clean-Up System continuously draws water from the reactor and passes it through a filter-demineraliser system to control conductivity and remove impurities. This has the combined effect of reducing the potential for corrosion of fuel cladding, minimising the generation of corrosion products on internal surfaces and reducing the potential for corrosion products to become activated in the reactor core. Once treated, the water is returned to the reactor in the main

feed line. The quality of the water passing through the system is continuously monitored to ensure that the characteristics are within defined parameters and that the system is performing as expected. The reactor water is passed to the liquid effluent system for treatment only when the characteristics fall outside of those defined parameters, or if there is excess reactor water during start-up and shut down operations. Following treatment, this water is then returned to the Condensate Storage Tank and is available to be recycled back into the reactor water circuit.

- The Fuel Pool Clean-Up System and the Suppression Pool Clean-Up System use shared demineralisers to maintain the water quality in these parts of the UK ABWR. The characteristics of the water in these two areas are broadly similar, as water from the UK ABWR's suppression pool is pumped to the equipment lay-down pool during refuelling operations. At the end of refuelling, water from the reactor well is returned to the suppression pool where its quality continues to be managed by the Suppression Pool Clean-Up System. This represents an improvement on previous generations of the BWR which used water from the Condensate Storage Tank during refuelling operations, which was subsequently transferred to the liquid effluent system and then back to the Condensate Storage Tank. The quantity of water previously extracted from the Condensate Storage Tank per refuelling operation is approximately 2500 m^3 which has resulted in reducing the size of the Condensate Storage Tank and the inventory of water in the reactor circuit.

Recycling water throughout the UK ABWR mitigates the requirement to make liquid discharges from the steam circuit during the operational life of the facility. A disposal of liquid effluent from the steam circuit will only take place when the facility is decommissioned.

5.1.9. Argument 1i: Secondary Neutron Sources

Secondary neutron sources provide additional neutrons, at a controlled rate, to assist with reactor start-up. BWRs and PWRs generally use Antimony-Beryllium neutron sources which generate tritium through their use. The cladding for Antimony-Beryllium neutron sources is typically manufactured from stainless steel which is porous to tritium. Any tritium that is generated can therefore diffuse through the cladding and into the reactor coolant. The UK ABWR design will instead use Californium-252 as the start-up neutron source, rather than the usual Antimony-Beryllium type. An advantage of using Californium-252 rather than Antimony-Beryllium neutron sources, is that it does not promote the generation of tritium. The ABWR design also means that secondary neutron sources are only required during the start-up phase of the first fuel cycle. Due to the flexibility provided by the reactor design (as described in 5.1.3: Argument 1c: Efficiency of Fuel Use), whereby fuel with a range of burn-ups can be used, secondary neutron sources are unlikely to be required after the first cycle and can therefore be removed.

5.1.10. Argument 1j: Leak Tightness of Liquid, Gas and Mixed Phase Systems

The design of the UK ABWR includes the provision of containment and ventilation systems that are intended to ensure that radioactive substances are retained within designated facilities during normal and fault conditions and they only enter the environment via appropriately permitted routes. Containment systems are also provided to ensure that radioactive substances do not spread unnecessarily around the plant and generate additional quantities of radioactive waste by contaminating structures, equipment and workers. Collectively, these systems ensure that the radioactivity in discharges from the UK ABWR will be minimised.

Containment systems have common objectives related to worker safety and environmental protection which are delivered by effective design, manufacture, installation and operation. Environmental protection is delivered by compliance with design principles developed in accordance with the Office of Nuclear Regulation's (ONR) Safety Assessment Principles (SAP).

The design of the UK ABWR has evolved to enhance the leak tightness of the primary circuit by rationalising the amount of pipe work associated with plant operations and by improving the performance of welds, seals and connections. Where contained materials have the potential to be released, systems are provided for detection and containment in segregated ventilation systems and drains that are specific to the characteristics of the waste.

5.2. Claim 2: Minimise the Radioactivity in Radioactive Waste Disposed to the Environment

The UK ABWR employs a range of features to reduce the discharge or disposal of radioactivity from those radioactive wastes that are unavoidably created during operations.

The Arguments presented in support of this Claim are considered to demonstrate compliance with the standard BAT conditions (2) and the relevant requirements of the P&ID (1) as provided below:

- Condition 2.3.2(a) 'The operator shall use the best available techniques in respect of the disposal of radioactive waste pursuant to the permit to minimise the activity of gaseous and aqueous radioactive waste disposed of by discharge to the environment.'
- Condition 2.3.3(a) 'The operator shall use the best available techniques to exclude all entrained solids, gases and non-aqueous liquids from radioactive aqueous waste prior to discharge to the environment.'

This is also considered to fulfil the following requirements of the P&ID:

- Minimising (in terms of radioactivity) discharges of gaseous and aqueous radioactive wastes.

The UK ABWR design contains a range of features that contribute to the substantiation of this Claim including:

- Provision of an Off-Gas system which includes processes to reduce radioactivity in the gaseous phase prior to discharge to the environment;
- Provision of Off-Gas Charcoal Adsorber within the Off-Gas system to abate short lived fission products;
- Heating Ventilation and Air Conditioning (HVAC) system that prevents the uncontrolled discharge of radioactive substances; and,
- Recirculation systems provided with abatement techniques that minimise the amount of liquid effluent that requires disposal during the operational life of the facility.

In developing the Arguments presented to demonstrate the validity of Claim 2 the REPs have been taken into account, with the following REPs considered specifically relevant:

- **Principle ENDP15** 'Best available techniques should be used to prevent and/or minimise releases of radioactive substances to the environment, either under routine or accident conditions.'
- **Principle ENDP16** 'Best available techniques should be used in the design of ventilation systems.'
- **Principle DEDP4** 'Aerial or liquid radioactive discharges to the environment during decommissioning should be kept to the minimum consistent with the decommissioning strategy for the site.'
- **Principle ENDP10 '**Facilities should be designed and equipped so that best available techniques are used to quantify the gaseous and liquid radioactive discharges produced by each major source on a site.'
- **Principle ENDP14 '**Best available techniques should be used for the control and measurement of plant parameters and releases to the environment, and for assessing the effects of such releases in the

environment.'

5.2.1. Argument 2a: Off-Gas System

Gaseous radioactive wastes will be generated during the operation of the reactor. Significant efforts are expended to eliminate these wastes but the disposal of gaseous waste to the environment is required to ensure the safe and efficient operation of the power station. Some of the radionuclides that are carried in the steam do not condense in the condenser. These radionuclides are carried by the steam jet air ejector, which is used to maintain the vacuum in the condenser, and require treatment and disposal as gaseous radioactive waste.

The design of the UK ABWR includes an Off-Gas system which collects, conveys, treats and discharges gaseous radioactive waste from the condenser. The system includes processes to reduce radioactivity in the gaseous phase prior to discharge to the environment. A separate Argument is presented for the most significant treatment process which is decay storage of noble gases (refer to 5.2.2: Argument 2b: Off-Gas Charcoal Adsorber for Noble Gases and Iodine) and filtration of airborne particulate matter (refer to 5.2.4: Argument 2d: Abatement of gaseous radioactive waste).

The Off-Gas system is configured to ensure that wastes with similar properties are segregated until any necessary processing has been undertaken.

The gaseous waste passes through High Efficiency Particulate Air (HEPA) filters before it is discharged up the stack. HEPA filters are specified to address the specific properties of the off-gas once it has passed through the Off-Gas Charcoal Adsorber and to ensure the removal of any very fine particulate matter that may be present. Some of the radionuclides in the off-gas such as tritium and Carbon-14 do not undergo treatment in the Off-Gas system and are discharged directly to the environment via the stack. This is because assessment of treatment techniques for these radionuclides has shown that the reduction in impacts on members of the public and the environment is low whilst the costs of installation and operation are very high. Installation of such equipment is therefore considered to be grossly disproportionate to any benefit that would be realised.

5.2.2. Argument 2b: Off-Gas Charcoal Adsorber for Noble Gases and Iodine

Low concentrations of fission products such as noble gases and iodine will be present in the off-gas from the reactor (refer to 5.1.1: Argument 1a: Design, Manufacture and Management of Fuel). The concentration of these fission products will increase in the event of a failure in the fuel cladding. The majority of these fission products have relatively short half-lives and undergo rapid decay. Retention of the gaseous fission products in the Off-Gas system for a period prior to discharge reduces the amount of radioactivity that will enter the environment.

The design of the UK ABWR's Off-Gas system includes an Off-Gas Charcoal Adsorber. The purpose of the Off-Gas Charcoal Adsorber is to retain the fission products for a defined period during which time they undergo radioactive decay. The chemical properties of the fission products and activated charcoal define the rate at which the fission products are adsorbed on to and de-adsorbed from the surface of the activated charcoal. The Off-Gas Charcoal Adsorber has been designed to retain isotopes of Xenon for a period of approximately 30 days and isotopes of Krypton for approximately 40 hours. Calculations have been undertaken that show that the use of the Off-Gas Charcoal Adsorber reduces the amount of radioactive noble gas discharged to the environment to 1/5000 of the level leaving the reactor. The calculations used to design the Off-Gas Charcoal Adsorber have not specifically taken account of the presence of isotopes of iodine. However, assessment has demonstrated that, as a result of a combination of the high boiling point of iodine and the properties of the activated charcoal in the Off-Gas Charcoal Adsorber, the Off-Gas Charcoal Adsorber is nevertheless effective at reducing the amount of iodine that is discharged to the environment.

Evolution of the (A)BWR design has introduced a number of improvements to the system for retaining noble gases and iodines. These improvements have increased the length of time that noble gases are retained within the Off-Gas system, from one day for all gaseous wastes to the current 30 days for isotopes of Xenon and 40 hours for isotopes of Krypton. They have also contributed to reducing the amount of iodine discharged. Further improvements to this system are not considered necessary because analysis has shown that the cost associated with increasing the capacity of the Off-Gas Charcoal Adsorber is significant and the reduction in the amount of noble gases and iodine that would be discharged is very small.

5.2.3. Argument 2c: Heating, Ventilation and Air-Conditioning System

Gaseous radioactive waste must be discharged to the environment via appropriately permitted outlets. The air pressure in facilities handling radioactive substances are typically maintained at a lower level than atmospheric pressure to ensure that air flows into the facility from the external environment pressure. This prevents the uncontrolled discharge of any radioactive substances through doors, windows and gaps in the building fabric. The negative pressure within the facility is maintained by a ventilation system which continuously discharges waste air to the environment.

The design of the UK ABWR also includes an HVAC system which delivers the combined function of:

- Preventing the uncontrolled discharge of radioactive substances;
- Providing a pleasant working environment for workers;
- Ensuring optimal working conditions for plant and equipment; and
- Delivering safety related functions to protect workers in the event of a release of radioactivity.

The configuration of the HVAC system ensures independent operation of sub-systems in principle areas of the plant. It also makes efficient use of the air that is drawn in to the system by allowing it to flow from areas of lower contamination risk to areas of higher contamination risk. HVAC sub-systems that serve areas of the plant where radioactive substances are present have filters to remove any particulate matter prior to the discharge of waste air to an appropriately permitted outlet. The approach to selecting the filter type appropriate for the characteristics of the gaseous waste is described in a separate argument.

HVAC sub-systems that serve areas of the plant where radioactive substances are handled do not provide any abatement other than filters. Additional abatement systems are not considered necessary because, under normal operations, the amount of radioactivity that is expected in the large volumes of waste air drawn through the HVAC system will be very low. Operational experience and feedback obtained from operating (A)BWRs demonstrates that the concentration of gaseous radioactivity in areas served by the HVAC system is very low. Assessment has shown that the cost of installing abatement equipment that is capable of treating such large volumes of waste air is very high and is considered grossly disproportionate to any benefit that would be achieved.

5.2.4. Argument 2d: Abatement of gaseous radioactive waste

The UK ABWR will employ appropriate filtration techniques to ensure that the concentration of particulate matter within the gaseous radioactive waste stream is minimised during normal and accident conditions. Filtration is considered to be RGP in the UK nuclear industry for the abatement of particulate matter and it is the design intent to provide filtration on the UK ABWR HVAC system as appropriate.

The UK ABWR has been subject to considerable optimisation, resulting in the amount of particulate matter that has the potential to become mobilised within the HVAC systems being minimised. As such, during normal operations, concentrations of particulate matter are not expected to be significant. The number and specification of the filters to be used to abate airborne particulate matter will be determined through the application of BAT. However, it is likely that filter selection will be influenced by the performance requirements necessary to mitigate accident conditions. It is therefore likely that the performance of the filters will be greater than that determined to be BAT for normal operations.

The gaseous radioactive waste will contain tritium and Carbon-14 which will not undergo treatment and be discharged directly to the environment via the stack. This is because the assessment of treatment techniques for these radionuclides has shown that the costs of installation and operation of treatment techniques are very high and the reduction in impacts on members of the public and the environment is low. Installation of such equipment is therefore considered to be grossly disproportionate to any benefit that would be realised.

5.2.5. Argument 2e: Minimisation of Evaporative Losses from Spent Fuel Pool

The design of the UK ABWR aims to minimise the amount of gaseous radioactive waste that evolves from Spent Fuel Pool. Temperature controls are provided on pool to minimise the potential for evaporative losses. However, a small amount of water vapour is expected to be released via the HVAC system as a result of evaporation. The radioactivity of any evaporate will be monitored by continuous air monitors located in the HVAC system to ensure that temperature control systems are working effectively.

5.2.6. Argument 2f: Configuration of Liquid Management Systems

Significant efforts have been made to minimise the generation of liquid radioactive waste. However, the safe and efficient operation of the UK ABWR requires that some radioactive liquids are disposed of to the environment, after appropriate treatment.

The design of the UK ABWR includes a liquid effluent system that collects, conveys and discharges aqueous radioactive wastes. Where practicable, aqueous radioactive waste is treated prior to its discharge to the environment. The system includes filtration, demineralisation and evaporation processes to remove certain materials and radionuclides which are considered in separate arguments (5.2.10: Argument 2j: Filtration of Aqueous Particulate Matter), (5.2.8: Argument 2h: Demineralisers to Maintain the Quality of Process Liquids), (5.2.11: Argument 2k: Evaporation of High Conductivity Liquids) respectively. The design has been developed by adopting a series of design policies that describe principles relating to the minimisation, segregation and containment of radioactive liquid effluent.

There is a system of segregated drains that allow wastes with broadly similar characteristics to be collected independently prior to the application of any treatment. The four drainage systems are:

- Low Conductivity Waste;
- High Conductivity Waste;
- Laundry waste (including shower drain); and,
- Controlled area drain waste.

The segregated drainage system ensures that treatment techniques can be targeted on specific characteristics of the waste which minimises the impacts of interference from other waste properties and enhances the overall performance of the effluent management system. Treated effluent that meets the criteria for re-use within the reactor circuit is sent to the Condensate Storage Tank where it mixes with condensate prior to being pumped back to the reactor. Operational experience and feedback from the (A)BWR fleet demonstrates that the quantity of liquid radioactive waste that is disposed of to the environment each year from the high conductivity drain is extremely low and that no liquid radioactive waste is disposed of from the low conductivity drain. The quantity of waste discharged from the other two drain systems each year is typically higher but, due to the source of these wastes, the radioactivity is very low.

Some of the radionuclides in the aqueous effluent such as tritium and Carbon-14 do not undergo treatment in the liquid effluent treatment system and are discharged directly to the environment. The majority of the techniques that could be used to treat these radionuclides have been shown to have very high installation and operating costs, whilst the impacts associated with discharges is low. It is therefore concluded that installation of such equipment is grossly disproportionate to any benefit that might be realised from their use.

5.2.7. Argument 2g: Sizing of Tanks, Vessels and Liquid Containment Systems

The relatively small volumes of liquid radioactive wastes that are generated from normal operation of the UK ABWR allow them to be managed, treated and discharged in discrete batches. This ensures that the characteristics of each batch of liquid waste can be determined prior to selecting the most appropriate form of treatment and disposal.

The design of the UK ABWR includes a series of tanks to manage the liquid wastes from the various drain systems provided across the plant. These tanks have been designed to provide the capacity necessary to store the effluent during treatment and prior to discharge. There are a separate series of tanks for each of the following:

- Low Conductivity Waste;
- High Conductivity Waste;
- Laundry waste (including shower drain); and,
- Controlled area drain waste.

The tanks provide sufficient capacity to accumulate effluent from operational activities and expected events. The capacity of tanks and vessels required to contain liquid wastes generated as a result of fault conditions will be determined as part of the fault studies. The size of the tanks ensure that operators have enough time to undertake sampling and analysis of wastes prior to making any decisions to discharge effluent to the environment or to subject it to additional treatment. All tanks are fitted with a series of alarms that indicate when the tank contents reach a pre-defined volume of liquid. In addition, all tanks are contained within bunds to capture any spills from over-filling. Operational experience and feedback has demonstrated that the size of the tanks and associated bunds are appropriate, because there has never been an instance where an operator has been required to make a non-routine discharge due to shortage of storage capacity in the tanks or bunds. The capacity of tanks, vessels and liquid containment systems will be further assessed as part of the fault studies to ensure that sufficient capacity is provided to contain liquid wastes that result from fault conditions.

5.2.8. Argument 2h: Demineralisers to Maintain the Quality of Process Liquids

Some of the fission products and activation products, such as isotopes of caesium, iodine, cobalt and manganese, dissolve in the water coolant. The presence of these soluble radionuclides is considered undesirable, even at low concentrations, because of the potential for occupational exposure to workers during operations, as well as harm to members of the public and the environment from any discharges. Demineraliser (also referred to as ion-exchange) systems are employed throughout the nuclear industry to remove soluble radionuclides from liquid processes and to allow the radioactivity to be managed as a solid waste.

The design of the UK ABWR includes the provision of demineralisers on systems for maintaining the quality of process liquids used in the reactor, the fuel pool and the suppression pool. The demineralisers are designed to allow the use of a variety of different media that are selected by the operator of the plant to fulfil their operational needs and to be compatible with subsequent disposability requirements. The demineralisers will ensure that the concentration of fission products and activation products will be low when the time comes to dispose of the process liquids at the end of the reactor's life.

5.2.9. Argument 2i: Demineralisers for Distillates from the High Conductivity Waste Evaporator.

The evaporator in the High Conductivity Waste system is effective at removing the majority of the radioactivity from the distilled process liquors. However, some of the volatile radionuclides are carried over with the distillate and require treatment before the waste is discharged to the environment.

The design of the UK ABWR liquid effluent management system includes a demineraliser to remove the radionuclides that are dissolved in the distillate. Filtration is unnecessary as the evaporator retains solid matter in the concentrate. The demineraliser is capable of using a variety of resins which allows the operator to make its selection based on operating requirements, compatibility with subsequent disposability requirements and any prevailing regulatory requirements.

Operational experience and feedback has demonstrated that the demand on the demineraliser is low and that it acts as a 'polishing unit'. Assessment has demonstrated that the cost associated with increasing the capacity and performance of the demineraliser systems is high compared to the relatively small reduction in discharges that would be achieved. Implementation of such improvements are, therefore, considered to be grossly disproportionate to the benefit that could be realised.

5.2.10. Argument 2j: Filtration of Aqueous Particulate Matter

Some activation products are present as particulate matter that is suspended in the liquid effluent. The presence of radioactive particulate matter is undesirable because it can result in increased occupational exposure to workers and harm to members of the public and the environment. Filtration of liquid process and effluent systems are used throughout the UK nuclear industry to remove particulate matter and to allow it to be managed as solid radioactive waste.

The design of the UK ABWR includes filters for liquid effluent systems. The current configuration of filtration systems is the result of a series of design evolutions implemented to improve the performance of both filters and related plant items. A notable example is the installation of high performance filters on the Laundry Drain System which reduces the radioactivity of liquid discharges.

The UK ABWR design provides a degree of flexibility in both the selection of filter media and the operation of filtration systems. The performance of filtration systems will therefore depend on parameters selected by the operator. Operational experience and feedback obtained from each generation of the (A)BWR has demonstrated that the progressive improvement of the filtration systems has had the effect of reducing discharges of radioactivity in liquid waste.

5.2.11. Argument 2k: Evaporation of High Conductivity Liquids

Liquid waste collected in the chemical drain contains substances with properties that interfere with waste treatment systems and can cause corrosion of process equipment. This high conductivity waste is segregated from the remainder of the low-conductivity process wastes. The impurities in high conductivity wastes must be removed before the water can be treated by demineralisation and returned to the process.

The design of the UK ABWR includes an evaporator to treat the high-conductivity waste and to remove the impurities. The evaporator has been designed to meet the rigorous demands of the nuclear industry and are standard components in (A)BWRs operating in Japan. The design of the evaporator has undergone a number of improvements to account for the increase in demand resulting from inclusion of floor drains in the high-conductivity waste stream. These improvements have further reduced the corrosion potential of the re-circulated high conductivity liquor and reduced the occurrence of scale that could impact on the performance of the evaporator.

Use of the evaporator allows a considerable fraction of the high-conductivity waste to be returned to the process. All liquid waste from the evaporator is passed through demineralisers that remove any soluble/volatile radionuclides that are carried over. The residues from the evaporator which contain the majority of the radioactivity are converted to solid waste. Operational experience and feedback has shown that discharges of liquid waste to the environment from the high-conductivity waste system are very infrequent. The low frequency of the discharges combined with the application of robust decontamination technologies are considered to represent BAT.

5.2.12. Argument 2l: Decay Storage of Solid and Liquid Wastes

Over a period of time the amount of radioactivity associated with all wastes will reduce by a physical phenomenon known as radioactive decay. The rate at which the radioactivity reduces depends on the 'half-life' which is different for each of the radionuclides that will be created in the UK ABWR. Storing solid and liquid radioactive waste before disposing of it to the environment or another premises will allow some of the radioactivity associated with the waste to decay and will reduce the amount of radioactivity that is disposed of in the waste. The reduction of radioactivity will be a function of the half-life of the radionuclides and the length of time over which the waste is stored.

The design of the UK ABWR includes a number of features that allow solid and liquid radioactive wastes to undergo decay during storage. Solid higher activity wastes such as activated reactor components and channel boxes are stored under water in a pool prior to being processed for either interim storage or disposal. An interim store for packaged Intermediate Level Waste (ILW) is to be constructed for the storage of all higher activity waste that cannot be disposed of from the site. This facility will, depending on the availability of a long-term solution for higher activity waste, store packaged ILW for up to 100 years. Sufficient capacity is being provided to store lower activity wastes for approximately two years which will allow any future operator to optimise the length of time over which they will accumulate waste in accordance with operational needs and prevailing regulatory requirements.

Liquids are continuously recirculated (including the low conductivity waste), cleaned up in the UK ABWR liquid treatment systems and re-used. Very little liquid effluent containing radioactivity is discharged to the environment (e.g. those not associated with the process).

5.3. Claim 3: Minimise the Volume of Radioactive Waste Disposed of to Other Premises

Considerable effort has been expended to minimise the production of radioactive wastes and to minimise the radioactivity of discharges to the environment through application of the Waste Hierarchy. However, the UK ABWR will inevitably create some wastes that will require disposal to other premises.

The Arguments presented in support of this Claim are considered to demonstrate compliance with the standard BAT conditions (2) as outlined below:

- Condition 2.3.2(b) ‘The operator shall use the best available techniques in respect of the disposal of radioactive waste pursuant to the permit to minimise the volume of radioactive waste disposed of by transfer to other premises.’

This is also considered to fulfil the following requirement of the P&ID (1):

- Minimising (in terms of mass/volume) solid and non- aqueous liquid radioactive wastes and spent fuel.

The UK ABWR design contains a range of features that contribute to the substantiation of this Claim including:

- Introduction of design changes that will minimise the volumes of operational and decommissioning waste arisings;
- Provision of a number of features that will allow any future operator to adopt an operating philosophy that will minimise the quantity of solid radioactive waste associated with routine operations and maintenance;
- Dedicated facilities for the management, treatment and storage of solid radioactive waste; and
- Reducing the quantity of solidified high conductivity wastes that are generated.

In developing the Arguments presented to demonstrate the validity of Claim 3 the REPs have been taken into account, with the following REP considered specifically relevant:

Principle RSMDP3 ‘the best available techniques should be used to ensure that production of radioactive waste is prevented and where that is not practicable minimised with regard to activity and quantity.’

5.3.1. Argument 3a: Design to Minimise the Volumes of Waste Arisings

The operation, maintenance and subsequent decommissioning of the UK ABWR will generate solid radioactive waste that will require management and treatment before it is consigned for either disposal to other premises or interim storage on-site. The design of the UK ABWR has evolved to reduce the quantities of solid radioactive waste that will be generated during its life-cycle and to ensure that those wastes that are unavoidably created are compatible with waste management techniques typically used in the United Kingdom. The design changes that have had the greatest impact on the volume of solid waste generated are as follows:

- Reactor Internal Pumps are used to circulate the water coolant around the reactor in the UK ABWR. These internal pumps have removed the pipework and associated plant used in previous evolutions to pump the water coolant and will contribute to a reduction in the quantity of waste generated from maintenance and decommissioning operations. Reactor Internal Pumps have the added benefits of reducing occupational exposure to workers, ensuring that the core remains covered with water in the event of an accident, decreasing the amount of power required to recirculate the water coolant and reducing the cost of vessels and pipework.
- The UK ABWR's Primary Containment Vessel is smaller than those used in previous evolutions of the BWR. This has the effect of reducing the size of radiologically controlled areas by approximately 15% which will reduce the quantity of waste generated from general occupancy, housekeeping and decommissioning.
- Introduction of techniques that reduce the amount of stress corrosion cracking experienced on reactor components. These techniques contribute to a reduction in the frequency that components require replacement as a result of corrosion. Consequently, this will result in a reduction in the quantity of waste associated with the replacement of damaged components and any related maintenance activities.
- Adoption of filtration and demineralisation techniques that have allowed the combination of the 'equipment' drain and the 'floor' drain. This reduces the quantity of concentrated waste from the evaporator and also reduced the quantity of pipework that will become radioactive waste when the plant is decommissioned.
- The introduction of hollow fibre filters (or pleated filters) that have eliminated the powder resin wastes that were generated on previous evolutions of the BWR from the use of pre-coat filters. The use of hollow fibre filters or pleated filters is expected to reduce the quantity of solid radioactive

waste by 27 tonnes per year.

The above improvements have been developed and implemented as a result of Hitachi-GE's on-going commitment to improving performance. Hitachi-GE has a comprehensive research and development programme that explores opportunities to reduce the materials used during construction and operations. This programme has ensured that those techniques that have been selected have been assessed for the contribution they make to enhancing performance across a range of requirements including the discharge of waste to the environment.

5.3.2. Argument 3b: Selection of Methods to Minimise Solid Waste Generation

The methods adopted by a future operator of the UK ABWR for operations and maintenance will influence the quantity of solid radioactive wastes requiring treatment, storage and disposal. The design of the UK ABWR includes a number of features that will allow any future operator to adopt an operating philosophy that will minimise the quantity of solid radioactive waste associated with routine operations and maintenance:

- Space is provided at key work locations within the designated areas that will allow operators and maintainers to segregate wastes depending on their physical, chemical, radiological and biological properties. This will ensure that wastes do not become unnecessarily cross-contaminated with substances that require more robust treatment, storage or disposal options;
- The provision of office accommodation outside of designated areas reduces occupancy and the associated generation of waste from office equipment and consumables;
- The provision of space to store tools, scaffolding and maintenance equipment within designated areas minimises the amount of equipment that is routinely used for maintenance activities and subsequently disposed of;
- The adoption of a flexible maintenance philosophy for non-critical items allows items to be replaced on the basis of the function that they serve rather than on a pre-defined schedule; and
- The allocation of space to store radioactive waste to take advantage of radioactive decay.

The flexibility afforded by these features provides any future operator with the degree of freedom needed to develop an approach that is appropriate to their operational needs and the regulatory requirements in-force at the time. It is therefore concluded that these features support the demonstration of BAT for minimising solid waste generation at this time.

5.3.3. Argument 3c: Application of Volume Reduction Processes to Solid Waste

All solid radioactive waste is stored, transported and disposed of in containers that have been designed to meet the requirements of relevant legislation. In the majority of cases the waste is disposed of in the container that it is transported in to the waste management facility. Making the most efficient use of space in containers has the combined effect of reducing the size of storage facilities, decreasing the number of vehicle movements during transportation and minimising the demand for disposal capacity at appropriately permitted disposal sites.

The design of the UK ABWR includes dedicated facilities for the management, treatment and storage of solid radioactive waste. These facilities will include a provision for managing control rods that have reached the end of their useful life. The following three viable control rod management options have been identified that require assessment:

- Store in a dry shielded facility without size reduction;
- Store within robust shielded container after size reduction; and

- Store within a container with cement grouting, after size reduction.

If size reduction of control rods is required this will be carried out within the ILW treatment building. The decision on how the control rods will be treated and subsequently stored will impact on the efficiency of storage and therefore the amount of space required. The assessment of available options will therefore include the requirement to demonstrate the application of BAT.

The UK ABWR will not include an on-site incinerator as the current best practice for volume reduction by combustion is to perform this task at an off-site industrial facility. Operational experience and feedback demonstrates that off-site facilities provide the same if not better performance than on-site incinerators.

The UK ABWR's solid radioactive waste management building has sufficient space and services to allow the introduction of a range of volume reduction techniques such as a waste compactor in addition, or as alternatives, to those specified in the design. This allows the future operator the flexibility to review the performance of techniques in the context of regulatory requirements and operating conditions prevailing at the time. The operator will be able to select the techniques most suited to current requirements. It is therefore considered that the combination of the defined volume reduction technology in the design and the flexibility to adopt alternatives in the future demonstrate the application of BAT at this stage.

5.3.4. Argument 3d: Solid Waste, Minimising the Quantity of Solidified High Conductivity Waste

High conductivity waste contains impurities that increase the risk of corrosion and the associated generation of corrosion products. High conductivity waste must be treated to make it suitable for either reintroduction to the process water system or for disposal as waste.

An evaporator is used to separate water from the impurities contained in the high conductivity waste. The evaporated water is collected, sampled and analysed prior to a decision on re-use or discharge to the environment. The concentrated liquor that remains in the evaporator contains all of the chemical impurities and the majority of the radioactivity associated with the high conductivity waste. This concentrated waste is solidified and subsequently disposed of as solid waste.

The design no longer includes the facility for making dry pellets from waste sludge because the volume of concentrated wastes has been substantially reduced by the use of a non-regeneration condensate demineraliser and this management step is thus no longer required. This improvement has resulted in an overall reduction in the solid waste produced from managing high conductivity wastes.

5.4. Claim 4: Optimise the Disposal Routes for Wastes Transferred to Other Premises

The design of the UK ABWR's radioactive waste building includes the space and services that are required to install the equipment necessary to undertake characterisation, treatment and storage of wastes to enable a future operator to select the optimal waste disposal route for radioactive solid wastes.

The Arguments presented in support of this Claim demonstrate compliance with the standard BAT conditions (2) and the relevant requirements of the P&ID (1) as provided below:

- Condition 2.3.3 (b) 'Characterise, sort, segregate solid and non-aqueous liquid wastes, to facilitate the disposal by optimised disposal routes.'

This is also considered to fulfil the following requirement of the P&ID:

- Selecting optimal disposal routes (taking account of the Waste Hierarchy and the proximity principle) for those wastes.

The UK ABWR design contains a range of features that contribute to the substantiation of this claim including:

- An agreement in principle will be obtained for those lower activity wastes that will be generated during the lifetime of the UK ABWR.
- Disposability assessments have been prepared for higher activity wastes.

In developing the Arguments presented to demonstrate the validity of Claim 4 the REPs have been taken into account, with the following REPs considered specifically relevant:

- **Principle RSMDP7** 'When making decisions about the management of radioactive substances, the best available techniques should be used to ensure that the resulting environmental risk and impact are minimised.'
- **Principle RSMDP10** 'Radioactive substances should be stored using the best available techniques so that their environmental risk and environmental impact are minimised and that subsequent management, including disposal is facilitated.'
- **Principle RSMDP13** 'The best available techniques, consistent with relevant guidance and standards, should be used to monitor and assess radioactive substances, disposals of radioactive wastes and the environment into which they are disposed.'
- **Principle RPDP3** 'Non-human species should be adequately protected from exposure to ionising radiation.'

5.4.1. Argument 4a: Provision of Waste Management Facilities

A range of facilities and equipment are required to deliver the effective and efficient use of available waste management routes. The design of the UK ABWR's radioactive waste building includes the space and services that are necessary to install the equipment necessary to undertake the characterisation, sorting, treatment and storage of waste prior to consignment to an appropriately permitted waste management service supplier. These facilities reflect the outputs of the waste strategy that has been developed for the wastes that will be produced by the UK ABWR. The specification and selection of equipment used within the radioactive waste management building will be undertaken by the future operator. The current size and configuration of the radioactive waste management building is considered to offer any future operator the flexibility to make a range of choices that will reflect its operational needs and the regulatory requirements in force at the time. The provision of such a flexible facility is considered to represent BAT at this stage.

5.4.2. Argument 4b: Optimal disposal route selection

The UK Government and Devolved Administrations published a revised policy for the long term management of solid LLW in 2007. This policy recognised that the previous preference for disposing of LLW from nuclear sites to the national LLW repository was no longer sustainable and that alternatives for the management of these wastes were required: the policy requires nuclear operators to consider a range of options when developing plans for the management of solid LLW. These options are to be based on the Waste Hierarchy and are to take into account a broad range of environmental and sustainability principles in addition to those related to the risk of exposure to potentially harmful ionising radiation.

Since 2007 the nuclear industry and its suppliers have made significant progress in developing alternatives to the disposal of LLW to the national LLW Repository. A range of techniques have been implemented that allow LLW to be:

- Minimised at source;
- Re-used/recycled;
- Volume reduced prior to disposal; and
- Disposed of at alternative sites to the national LLW Repository.

The design of the UK ABWR, and the Radioactive Waste Management Arrangements (7) developed to manage the waste, acknowledge that a range of waste management options are available for the management of LLW that will arise during the operation of the power station. Strategic consideration of options related to the provision of on-site waste treatment facilities has concluded that incinerators, metal treatment and disposal facilities will not form part of the generic design for the UK ABWR. This decision is consistent with the findings of a number of strategic studies that are discussed further in subsequent Arguments (5.4.5: Argument 4e: Compatibility of Existing Waste BAT Studies). Evidence is provided to support the use of selected waste management techniques (including those provided by the national LLW Repository) for the disposal of LLW. It is recognised that this is a high level assessment that will require further review by any future operator.

The decision to select specific waste management options also takes account of recent permitting programmes at nuclear sites and recognises that there is now an established market for these treatment and disposal techniques. The compatibility of the UK ABWR’s waste with the conditions for acceptance of commercially available disposal routes is discussed further in argument (5.4.3: Argument 4c: Agreement in Principle for Waste Routes - Lower Activity Wastes).

The UK ABWR’s solid waste management facilities allow any future operator a high degree of flexibility in the selection and deployment of LLW treatment techniques as discussed in argument (5.4.1: Argument 4a: Provision of Waste Management Facilities). This will allow any future operator to review the availability and performance of LLW treatment/disposal techniques that are available at the time and to implement any measures required to ensure that their LLW is compatible with the conditions for acceptance for such techniques. The outcomes of such reviews will be included in the waste management plans that are required by the 2007 LLW policy and will demonstrate that BAT is being applied to the management of these wastes.

5.4.3. Argument 4c: Agreement in Principle for Waste Routes - Lower Activity Wastes

Each of the routes for solid and non-aqueous lower activity radioactive wastes has a series of requirements that the consignor of the waste must fulfil before it can be accepted. Compliance with these 'Waste Acceptance Criteria' is a requirement of the terms and conditions agreed between contracting parties. Compliance with Waste Acceptance Criteria is also a requirement of the Environment Agency's standard environmental permit template for disposals of radioactive waste from nuclear licensed sites as they are 'instructions' given by the person to whom the waste is consigned.

Hitachi-GE, as the requesting party for GDA will not dispose of waste. However, the GDA process requires that the requesting party obtains 'agreement-in-principle' to dispose of waste via each of the waste routes. This process provides assurance that the waste generated from operating, maintaining and decommissioning of the UK ABWR will comply with the Waste Acceptance Criteria for the waste routes and can be disposed of by any future operator.

Hitachi-GE is engaging with the suppliers of waste management services for solid and non-aqueous radioactive waste in the UK and shall obtained an agreement-in-principle for the following waste routes:

- Metallic waste for physical decontamination and recycling;
- Combustible waste for volume reduction by incineration;
- Very low activity waste for disposal at appropriately permitted commercial landfills;
- Supercompaction of compressible lower activity waste followed by disposal in the national Low Level Waste Repository; and,
- Disposal of non-compressible lower activity waste in the national LLW Repository.

The agreements-in-principle will demonstrate that lower activity wastes that will be produced by the UK ABWR are compatible with the range of waste routes and services available in the United Kingdom for such wastes. This is considered to represent BAT for the GDA process. The final choice of waste route and the quantity of waste to be consigned will be determined by the future operator.

5.4.4. Argument 4d: Disposability Assessments for Higher Activity Wastes and Spent Fuel

In common with all operating stations in the UK, some of the solid radioactive wastes that will be created on the UK ABWR will be too radioactive to be managed and disposed of via existing routes. These higher activity wastes and spent fuel will be stored until a long-term management solution is available. Any treatment and storage arrangements must accord with the current management and/or disposal concepts for these wastes. The Nuclear Decommissioning Authority's Radioactive Waste Management Directorate (RWMD) is the source of authoritative guidance regarding management and disposal concepts. RWMD undertakes assessments to determine the degree to which proposals for the management of higher activity waste and spent fuel accord with management and disposal concepts.

Hitachi-GE has engaged extensively with RWMD during the development of the GDA submission for the UK ABWR. Disposability assessments are being prepared in the following areas:

- Disposal of higher activity waste in the proposed national Geological Disposal Facility; and,
- Disposal of spent nuclear fuel in the proposed national Geological Disposal Facility.

It is envisaged that the disposability assessments will demonstrate that higher activity waste that will be produced by the UK ABWR will be compatible with the range of waste routes and services available in the United Kingdom for such wastes. For the spent fuel it is envisaged that a disposability assessment will demonstrate that there are methods currently available which are used successfully in other countries and could be designed and implemented to comply with UK Regulatory and disposability requirements. This is considered to represent BAT for the GDA process. The final choice of waste and spent fuel routes and the quantity of waste to be consigned will be determined by the future operator.

5.4.5. Argument 4e: Compatibility of Existing Waste BAT Studies

Selection of appropriate waste routes is an important element of demonstrating that waste management practices form part of an integrated strategy that is focussed on waste minimisation and application of the Waste Hierarchy and demonstrating the application of BAT. A series of studies have been prepared by the LLW Repository Ltd at the request of the Nuclear Decommissioning Authority to examine the degree to which certain waste routes underpin the development of integrated waste strategies for producers of radioactive waste and so underpin delivery of the Waste Hierarchy. These studies adopted a systematic, robust and transparent approach to determining the Best Practicable Environmental Option (BPEO) for groups of radioactive waste with broadly similar characteristics.

Hitachi-GE has undertaken a series of assessments to determine the degree to which the findings of these studies are applicable to the following types of waste that will be generated by the UK ABWR:

- Metal waste that has radioactive contamination on its surfaces;
- Combustible wastes that are lightly contaminated with beta and gamma emitting radionuclides and/or very lightly contaminated with alpha emitting radionuclides; and,
- Waste with very low levels of radioactivity.

The assessments have concluded that the series of studies are applicable to the UK ABWR and that BAT is demonstrated at a strategic level for metallic wastes, combustible wastes and wastes with very low levels of radioactivity.

5.5. Claim 5: Minimise the Impacts on the Environment and Members of the Public from Radioactive Waste that is Disposed of to the Environment

The design of the UK ABWR has focussed on reducing the amount of radioactivity in gaseous and liquid wastes that are evolved during the operation of the facility. However, some radioactivity will still be discharged to the environment. Where discharges of radioactivity to air and water are unavoidable, techniques have been adopted to ensure that the subsequent impacts to the environment and members of the public are as low as reasonably achievable.
The Arguments presented in support of this Claim are considered to demonstrate compliance with the standard BAT conditions (2) as provided below:

- Condition 2.3.2(c) The operator shall use the **best available techniques** in respect of the disposal of radioactive waste pursuant to the permit to Dispose of radioactive waste **at times, in a form, and in a manner** so as to **minimise the radiological effects** on the environment and members of the public.

This is also considered to fulfil the following requirement of the P&ID:

- Minimising the impact of those discharges on people, and adequately protecting other species.

The UK ABWR design contains a range of features that contribute to the substantiation of this Claim including:

- Minimising the impact of discharges to the environment by means of optimising the design and operation of any discharge outlets.

In developing the Arguments presented to demonstrate the validity of Claim 5 the REPs have been taken into account, with the following REPs considered specifically relevant:

- **Principle RSMDP7** 'When making decisions about the management of radioactive substances, the best available techniques should be used to ensure that the resulting environmental risk and impact are minimised.
- **Principle ENDP14 '**Best available techniques should be used for the control and measurement of plant parameters and releases to the environment, and for assessing the effects of such releases in the environment.'
- **Principle RPDP1** 'All exposures to ionising radiation of any member of the public and of the

population as a whole shall be kept as low as reasonably achievable ALARA), economic and social factors being taken into account.'

- **Principle ENDP2** 'Radiological impacts to people and the environment should be avoided and where that is not practicable minimised commensurate with the operations being carried out.'
- **Principle ENDP16** 'Best available techniques should be used in the design of ventilation systems.'
- **Principle DEDP3** 'Facilities should be designed, built and operated using the best available techniques to minimise the impacts on people and the environment of decommissioning operations and the management of decommissioning wastes.'

5.5.1. Argument 5a: Gaseous Discharge System - Main Stack

Significant efforts have been expended to remove radioactivity from gaseous wastes generated in the UK ABWR but some radioactivity will be discharged to the environment. The location and timing of these discharges will have a direct bearing on the impact to members of the public and the environment from operations of the UK ABWR.

The majority of the gaseous radioactive waste will be discharged via the main stack which is located on the roof of the reactor building. The main stack receives gaseous wastes from the gaseous waste treatment systems and building ventilation systems. The location of the main stack has been selected because of its proximity to the systems that feed into it, the height provided by the reactor building of which it is part and the structural strength of the reactor building. Modelling of the impacts associated with discharges will be undertaken to demonstrate the relationship between the height of the stack and the impact to members of the public from the radioactivity of the waste that is discharged. The assessment will also consider the costs of the engineering associated with increasing stack height and explore at what point further increases in the height of the stack is grossly disproportionate to the benefits that are realised from reductions in impacts to members of the public and the environment.

The design of the UK ABWR's main stack includes the provision of equipment that allows for sampling of gaseous radioactive waste that is discharged to the environment. This equipment is compatible with a wide range of proprietary techniques that allow either real-time or off-line analysis of gaseous wastes. The selection of the techniques for sampling and analysis of waste shall be made by the future operator of the power station. The future operator shall also be responsible for defining the environmental monitoring programme which will allow the actual impacts on members of the public and the environment from discharges to be determined.

5.5.2. Argument 5b: Gaseous Discharges - Minor Sources

Gaseous radioactive waste will be generated in ancillary buildings such as the interim spent fuel store, and the interim ILW store that are not connected to the main stack. This waste will be collected by the buildings' ventilation systems and undergo treatment, where applicable, prior to being disposed of from stack or ventilator as necessary.

5.5.3. Argument 5c: Liquid Effluent System

Significant efforts have been expended to remove radioactivity from liquid wastes that are generated in the UK ABWR, but some radioactivity will be discharged to the environment. The location and timing of these discharges will have a direct bearing on the impact to members of the public and the environment from operations of the UK ABWR.

All of the radioactive liquid effluent will be discharged with the sea water that is used to condense the steam and to provide emergency cooling. The flow rate of sea water through the UK ABWR will depend on the operational status of the reactor unit and will be between 6,100m^3/hr and 185,000m^3/hr.

The design of the UK ABWR's liquid effluent management system allows the timing of the discharges to be controlled to take account of any prevailing environmental conditions and regulatory requirements. The cooling water will be discharged into the sea adjacent to the location of the UK ABWR. The exact position of the discharge point will be defined by the future operator of the power station. The models used to determine the impacts to members of the public and the environment from liquid effluent discharges reflect the generic site description and are insensitive to the position of the discharge provided it is within 10km of the site and within 5km of the shore. Assessment of the discharges using these models has demonstrated that the impacts of the discharges will be very low.

The design of the UK ABWR's liquid effluent management system includes equipment that allows the effluent to be sampled prior to discharge to the environment. This allows the operator to undertake analysis and to be satisfied that the characteristics of the waste conform with any specific limitations and conditions within the site's environmental permit. The design does not currently include equipment that allows the effluent to be sampled during the discharge. Assessment is currently underway to determine the practicability of installing equipment to take samples of the discharge and allow the operator to provide a true and accurate record of the radioactivity discharged to the environment. This equipment is compatible with a range of proprietary sampling and analytical techniques. The selection of the techniques for sampling and analysis of waste shall be made by the future operator of the power station. The future operator shall also be responsible for defining the environmental monitoring programme which will allow the actual impacts on members of the public and the environment from discharges to be determined.

6. Conclusion

The Claims and Arguments for the UK ABWR Demonstration of BAT have been developed using information held by Hitachi-GE. Substantiation of these Claims and Arguments will be achieved through the provision of supporting Evidence as part of Step 2 and subsequent GDA steps. The Evidence will reflect the information used to develop the Claims and Arguments presented in this report and the outcome of ongoing assessments.

Collectively the Claims-Arguments-Evidence model will support the demonstration that BAT has been applied to the UK ABWR design, allowing examination and challenge and where applicable identifying key gaps or uncertainties. In gathering Evidence Hitachi-GE will ask the questions:

- Can anything else be done to reduce activity of discharges, minimise volumes of solid waste or reduce impacts from discharges?
- Is the time, trouble and money associated with implementing changes grossly disproportionate to the potential benefits gained?

The process of gathering Evidence is in progress: existing sources are being reviewed whilst additional assessment is underway to underpin areas where insufficient documented Evidence exists. Existing sources will include, but not be limited to, analytical data, research and development, trials and modelling.

The demonstration of BAT is an iterative process that feeds back to the design; if at the end of the process any areas of insufficient evidence remain, design changes may be required to support the demonstration of the application of BAT.