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UK ABWR

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UK ABWR Generic Design Assessment

Approach to Optimisation

Hitachi-GE Nuclear Energy, Ltd.

HITACHI

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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)
OG	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
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, March 2013, Environment Agency.

2 Demonstration of BAT, GA91-9901-0023-00001, XE-GD-0097, Rev C, March 2014, Hitachi-GE.

3 Regulatory Guidance Series, No. RSR 2, The regulation of radioactive substances activities on nuclear licensed sites, Version 2, August 2012, Environment Agency.

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

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

6 Regulatory Guidance Series, No. RSR 1, Radioactive Substances Regulation – Environmental Principles, version 2, April 2010, Environment Agency.

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

8 Environmental Permitting (England and Wales) Regulations 2010.

9 Environmental Permitting (England and Wales) (Amendment) Regulations 2011.

10 Criteria for setting limits on the discharge of radioactive waste from nuclear sites, Issue 1, June 2012, Environment Agency.

11 Best Available Techniques (BAT) for the Management of the Generation and Disposal of Radioactive Wastes, A Nuclear Industry Code of Practice, Issue 1, December 2010, Prepared on Behalf of the Nuclear Industry Safety Directors Forum.

3. Introduction

The Environment Agency's requirements for undertaking environmental optimisation of discharges of radioactivity and to demonstrate the application of Best Available Techniques (BAT) for the GDA submission are defined within their Process and Information Document (P&ID) (1).

This report presents the methodology adopted by Hitachi-GE to demonstrate that the environmental performance associated with the practice of generating electricity from the UK ABWR is optimised, and that impacts from potentially harmful ionising radiation on members of the public and the environment are minimised. In line with Relevant Good Practice (RGP), the Claim-Argument-Evidence model is utilised.

The Claims generated as part of this process, along with their accompanying Arguments, are presented in the 'Demonstration of BAT' report (2) (also submitted for the Environment Agency's initial assessment). 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 submitted to the Environment Agency for initial assessment.

4. Regulatory Context

Optimisation is a key element of protecting people from the risks associated with exposure to potentially harmful ionising radiation. Optimisation applies only to radiological risks to people; other living organisms must also be protected from radiological hazards but there is no optimisation requirement.

This section explores the policy, legislative and regulatory context related to optimisation. It also identifies relevant regulatory and industry guidance available to support the development of Hitachi-GE's approach to environmental optimisation and demonstration of BAT.

4.1. Principles of Optimisation

Current legislation and practices associated with radiological protection are based on the 1990 Recommendations of the International Commission on Radiological Protection (ICRP60). ICRP60 states, in the context of optimisation, that:

> *In relation to any particular source within a practice, the magnitude of individual doses, the number of people exposed, and the likelihood of incurring exposures where these are not certain to be received should all be kept as low as reasonably achievable, economic and social factors being taken into account. This procedure should be constrained by restrictions to the doses to individuals ('dose constraints'), or the risks to individuals in the case of potential exposures ('risk constraints'), so as to limit the inequity likely to result from the inherent economic and social judgements (the* ***optimisation*** *of protection).*

The principles of ICRP60 that relate to optimisation have subsequently formed the basis of principles included in the international standards and directives presented in Table 4.1-1.

Table 4.1-1: Principles of Optimisation

Source	Summary of optimisation principles
IAEA Basic Safety Standards (GSR3 Principle 5)	Protection must be optimised to provide the highest level of safety that can reasonably be achieved
International Commission on Radiological Protection (ICRP 103, 2007 Recommendations)	The process of determining what level of protection and safety makes **exposures**, and the probability and magnitude of potential exposures, **as low as reasonably achievable**, **economic and societal** factors being taken into account
European Basic Safety Standards Directive 1996 (Article 6, para 3a)	In the context of optimisation all exposures shall be kept **as low as reasonably achievable, economic and social factors** being taken into account
European Basic Safety Standards Directive – Proposal 2011.	Optimisation means a forward looking **iterative process** to establish adequate protection measures taking into account the **prevailing circumstances**, the **available options**, and the **nature** of the exposure situation, with the aim of keeping the magnitude and likelihood of exposure and the number of people exposed **as low as reasonably achievable**.

The OSPAR Convention for the Protection of the Marine Environment of the North East Atlantic was agreed in 1992. Countries that have either a North East Atlantic coast or discharge into the OSPAR maritime area via their rivers are Contracting Parties to the Convention. Environment agencies in the UK have a duty to implement the general requirements of the OSPAR Convention. At the 1998 Ministerial meeting of the OSPAR Commission, the Contracting Parties agreed a strategy with regard to radioactive substances with the following intentions:

- ***Overall objective****: To prevent pollution of the maritime area, as defined under the Convention, from ionising radiation, through progressive and substantial reductions of discharges, emissions and losses of radioactive substances. The ultimate aim is to achieve concentrations in the environment near background values for naturally occurring radioactive substances and close to zero for artificial radioactive substances. In achieving this objective, the following issues should, inter alia, be taken into account:*

    - *legitimate uses of the sea;*
    - *technical feasibility;*
    - *radiological impacts to man and biota.*

- ***Intermediate objective (2020)****: By the year 2020, the OSPAR Commission will ensure that discharges, emissions and losses of radioactive substances are reduced to levels where the additional concentrations in the marine environment above historic levels, resulting from such discharges, emissions and losses, are close to zero.*

Annex A of the strategy agreed during the 1998 Ministerial meeting provides a definition of BAT as applied to reducing discharges, emissions and losses of radioactive substances to the maritime area.

4.1.1. Policy and Regulatory Requirements

The concept of BAT is used in two significant environmental regulatory regimes in England and Wales:

- Schedule 1 of the Environmental Permitting Regulations which enact the requirements of the Industrial Emissions Directive (formally the IPPC Directive), and
- Radioactive substances regulation (RSR).

Both regimes use the same terminology and have a similar definition for BAT. The difference between the application of BAT under the different regimes reflects their different legal and policy requirements. There is also a wide body of detailed technical standards developed for non-nuclear ('non-RSR') BAT through the European 'BREF Notes'. Such European standards are not available for RSR BAT. In RSR, a principle-based approach which is developed through consideration of the REPs and other supporting guidance (3) is adopted.

4.2. Statutory Requirements and Government Policy

Government policy has evolved over many years to address the optimisation requirements placed on the UK by international obligations and treaties. Key elements of Government policy that are considered relevant to optimisation are presented in Table 4.2-1:

Table 4.2-1: Statutory Requirements and Government Policy relating to Optimisation

Source	Summary of requirements
UK Strategy for Radioactive Discharges 2009	Implements OSPAR requirements. States that UK Government considers the unnecessary introduction of radioactivity into the environment as undesirable even if doses are low and unlikely to cause harm. States that, in setting discharge limits, the regulators will have regard to the application of BAT.
Statutory Guidance to the Environment Agency (2009)	Requires the Environment Agency pursue the objectives stated in the Strategy for Radioactive Discharges and in particular to apply a number of principles which include: - Optimisation of protection - Application of limits and conditions to control discharges - The use of BAT - The use of the 'Precautionary Principle' - The preferred use of 'Concentrate and Contain' over 'Dilute and Disperse'

Solid Low Level Waste Policy 2007	Plans required for the management of LLW at all nuclear sites. Consideration of all practicable options for the management of LLW. Use of the waste hierarchy (prevent, re-use, recycle, recover, dispose). Use of a risk-informed approach to ensure that doses to people from disposals are as low as reasonably achievable.

4.3. Legislation and Regulations

The disposal of radioactive waste from a nuclear licensed site in England and Wales is subject to the provisions of the Environmental Permitting (England and Wales) Regulations 2010 (8). These regulations were subsequently amended by the Environmental Permitting (England and Wales) (Amendment) Regulations 2011. In the context of optimisation, Part 4 of Schedule 23 of the Regulations (9) state that:

> *In respect of a radioactive substances activity that relates to radioactive waste, the regulator must exercise its relevant function to ensure that:*
>
> *(a) all exposure to ionising radiation of any member of the public and of the population as a whole resulting from the disposal of radioactive waste are kept as low as reasonably achievable, taking into account economic and social factors; and*
>
> *(b) the sum of the doses resulting from the exposure of any member of the public to ionising radiation should not exceed the dose limits set out in Article 13 of the Basic Standards Directive subject to the exclusions set out in Article 6(4) of that directive.*

These obligations are placed on the regulator who gives effect to these, and other requirements imposed by statutory guidance and Government policy, through permit conditions. The optimisation requirement is achieved by use of the permit conditions presented in Table 4.3-1.

The GDA P&ID document (1) states the requirement to undertake environmental optimisation and to demonstrate the application of BAT. The P&ID requirements are consistent with those conditions that would be included in a standard permit template that require the application of BAT (5). To ensure compatibility of the GEP application with all future site specific permit applications, and for consistency across the phases of the project, the BAT conditions contained within a standard permit template are used within the GDA Claim-Argument-Evidence approach. These permit conditions that require the application of BAT are therefore used to form the basis of the Claims within the Claim-Argument-Evidence model. For ease of reference, the applicable P&ID requirements are cross-referenced with the relevant BAT condition contained within the standard permit template.

Table 4.3-1: Environmental Permit Conditions and P&ID Requirements relating to Optimisation

No	Permit Condition	Equivalent P&ID Requirement
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.	Preventing and minimising (in terms of radioactivity) the creation of radioactive waste.
2.3.2	The operator shall use the best available techniques in respect of the disposal of radioactive waste pursuant to the permit to: (a) Minimise the activity of gaseous and aqueous radioactive waste disposed of by discharge to the environment; (b) Minimise the volume of radioactive waste disposed of by transfer to other premises: (c) 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.	Minimising (in terms of radioactivity) discharges of gaseous and aqueous radioactive wastes. Minimising the impact of those discharges on people, and adequately protecting other species. Minimising (in terms of mass/volume) solid and non- aqueous liquid radioactive wastes and spent fuel. The suitability for disposal of any wastes and spent fuel for which there is no currently available disposal route and how they will be managed in the interim so as not to prejudice their ultimate disposal.
2.3.3	The operator shall use the best available techniques to: (a) Exclude all entrained solids, gases and non-aqueous liquids from radioactive aqueous waste prior to discharge to the environment; (b) Characterise, sort, segregate solid and non-aqueous liquid wastes, to facilitate the disposal by optimised disposal routes	Selecting optimal disposal routes (taking account of the waste hierarchy and the proximity principle) for those wastes.

There is no statutory definition of BAT as it applies to radioactive substances activities. The Environment Agency uses the following definition of BAT (3) adopted by the Department of Energy and Climate Change (DECC) from the strategy agreed at the 1998 Ministerial meeting of OSPAR contracting parties.

- *The use of the best available techniques shall emphasise the use of non-waste technology, if available.*

- *The term "best available techniques" means the latest stage of development (state of the art) of processes, of facilities or of methods of operation which indicate the practical suitability of a particular measure for limiting discharges, emissions and waste. In determining whether a set of processes, facilities and methods of operation constitute the best available techniques in general or individual cases, special consideration shall be given to:*

- *comparable processes, facilities or methods of operation which have recently been successfully tried out;*
- *technological advances and changes in scientific knowledge and understanding;*
- *the economic feasibility of such techniques;*
- *time limits for installation in both new and existing plants; and*
- *the nature and volume of the discharges and emissions concerned.*

- *It therefore follows that what is "best available techniques" for a particular process will change with time in the light of technological advances, economic and social factors, as well as changes in scientific knowledge and understanding.*
- *If the reduction of discharges and emissions resulting from the use of best available techniques does not lead to environmentally acceptable results, additional measures have to be applied.*
- *"Techniques" include both the technology used and the way in which the installation is designed, built, maintained, operated and dismantled.*

4.4. Guidance

4.4.1. Regulatory Guidance

The Environment Agency has produced a number of guidance documents to promote understanding of environmental optimisation and the application of BAT. These documents provide details of the context in which environmental optimisation is to be undertaken and define the Environment Agency's expectations of processes to be adopted to demonstrate BAT. This guidance is summarised in Table 4.4.1-1.

Table 4.4.1-1: Statutory Requirements and Government Policy relating to Optimisation

Guidance Document	Summary of Contents Relevant to Environmental Optimisation
RSR: Principles of optimisation in the management of and disposal of radioactive waste (4).	Provides a definition of BAT Defines the legal and policy framework for optimisation Establishes the basis on which judgements have to be made Defines principles for optimisation Required a demonstration that BAT is being applied to achieve an optimised outcome
Regulatory Guidance Series, No RSR 2 The regulation of radioactive substances activities on nuclear licensed sites (3)	Guidance on how the Environment Agency regulates radioactive substances activities. Provides detailed interpretation of the radiation protection principles and comprehensive details on optimisation requirements.
Criteria for setting limits on the discharge of radioactive waste from nuclear sites (10)	States the requirement for operators to apply BAT Identifies relevant provisions of the statutory guidance that require limits to be set based on BAT Explains the relationship between BAT and discharge limits
Radioactive Substances Regulation – Environmental Principles (REPs) (6)	Forms part of consistent and standardised framework for technical assessments and judgements undertaken by Environment Agency

4.4.2. Nuclear Industry Guidance

A Code of Practice was prepared on behalf of the Nuclear Industry Safety Directors Forum (11). The Code of Practice details the principles, processes and practices that may be used when identifying and implementing BAT for the disposal of radioactive waste under an environmental permit.

4.5. Approach to Environmental Optimisation

4.5.1. Regulatory Environmental Principles

The BAT methodology presented here is considered to be consistent with industry RGP and takes into account the relevant REPs (6). Hitachi-GE's 'Consideration of and compliance with the REPs' report (7), details the approach undertaken by Hitachi-GE to review and incorporate each of the relevant REPs within the GDA submission. The document highlights the REPs specifically taken into account in each report. This Approach to Optimisation principally addresses the following REP:

Principle RSMDP4 'The best available techniques should be identified by a methodology that is timely, transparent, inclusive, based on good quality data, and properly documented.'

Through the implementation of this methodology, the following REPS are also addressed (amongst others):

RSDMDP3, RSDMDP5, RSDMDP6, RSDMDP7, RSDMDP8, RPDP1 and ENDP2.

4.5.2. 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 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.

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 must 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 has 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.

These principles will ensure that design iterations that have been demonstrated to improve performance are included within the UK ABWR design and that the requirements of the environmental permit are an integral part of decision making. Further opportunities to optimise the UK ABWR design can both be identified and subsequently realised subject to the demonstration of BAT (including the consideration of proportionality).

4.6. Basis for Selecting Proposed Approach

The application of BAT to the UK ABWR design will be demonstrated through the Claim-Argument-Evidence approach. The methodology outlined here is already widely used in the nuclear and other high hazard industries in the preparation of safety cases, including that of the UK ABWR (the PCSR). This approach is also being used progressively to demonstrate environmental compliance for a number of projects in the UK nuclear industry including:

- GDA submissions for the Westinghouse AP1000 and the Areva UK EPR;
- The Environmental Permit (RSR) application for the proposed new nuclear power station at Hinkley Point in Somerset;
- Construction of facilities to support decommissioning of the Dounreay Site in Northern Scotland; and
- Construction of metallurgical manufacturing facilities at Nuclear Defence sites in the UK.

The approach adopted by Hitachi-GE builds on the experience gained from these projects and recognises that:

- The UK ABWR design proposed within the GDA submission is an existing design for which operational experience and feedback is available that demonstrates the performance of waste and environmental systems. This experience is expected to make a significant contribution to demonstrating that BAT is being applied to optimise environmental performance.
- The UK ABWR is based on BWR technology that is being operated throughout the world. Extensive knowledge and experience has been developed which underpins the performance of BWRs and the associated impact of any design changes. This operational experience is considered to contribute further to the demonstration of BAT and this approach is consistent with guidance on environmental optimisation provided by the Environment Agency.
- The introduction of the ABWR to the UK market may require changes or refinements to the design to ensure that it meets the expectations of the regulatory community. For every element of the design that has a bearing on the generation or management of radioactive waste disposals and discharges the question will be asked: “Is there anything further that can be done?” The answer will be provided within the Evidence section of the Demonstration of BAT and will consider proportionality.

The approach set out within this document is considered by Hitachi-GE to reflect RGP within the UK nuclear industry for the delivery of environmental optimisation on large nuclear new build projects. The proposed methodology for demonstrating the application of BAT will enable Hitachi-GE to deliver an Environmental Optimisation Case that will achieve the following:

- Adoption of operational experience that demonstrates that the existing design has evolved through a number of design iterations, with the reduction of waste generation and discharges at the heart of the evolutionary process.
- Identification of opportunities to further optimise the UK ABWR and demonstration of those options that should be implemented, considering proportionality.
- A robust, defensible and transparent demonstration of compliance with the optimisation requirements of the P&ID and GEP conditions that require the application of BAT.
- Efficient and effective transfer of knowledge between the GDA submission and future applications by an operator for a site-specific permit.
- Consistent approaches/methodologies for the Demonstration of BAT and the safety case.

Feedback from the assessment of the GDA submissions and the Environmental Permit (RSR) application for Hinkley Point C indicates that adoption of the approach to environmental optimisation proposed by Hitachi-GE and the associated Claims-Arguments-Evidence methodology for demonstrating the application of BAT is acceptable to the Environment Agency.

5. UK ABWR BAT Methodology

Hitachi-GE has developed a methodology for demonstrating the application of BAT which breaks the process down into the main BAT-related permit conditions. Hitachi-GE will therefore be able to demonstrate that it has done everything possible (considering proportionality) to:

- Prevent and minimise (in terms of radioactivity) the creation of radioactive waste;
- Minimise (in terms of radioactivity) discharges of gaseous and aqueous radioactive wastes;
- Minimise the impact of those discharges on people, and adequately protect other species;
- Minimise (in terms of mass and volume) solid and non-aqueous liquid radioactive wastes and spent fuel;
- Select the optimal disposal routes (taking account of the waste hierarchy and the proximity principle) for those wastes; which also includes the suitability of disposal for those wastes where there is currently no available disposal route.

An overview of the BAT methodology employed is outlined in Figure 5-1. The italicised and numbered headings in the diagram indicate those key steps and activities for which further information is provided in the corresponding sub section of this report.

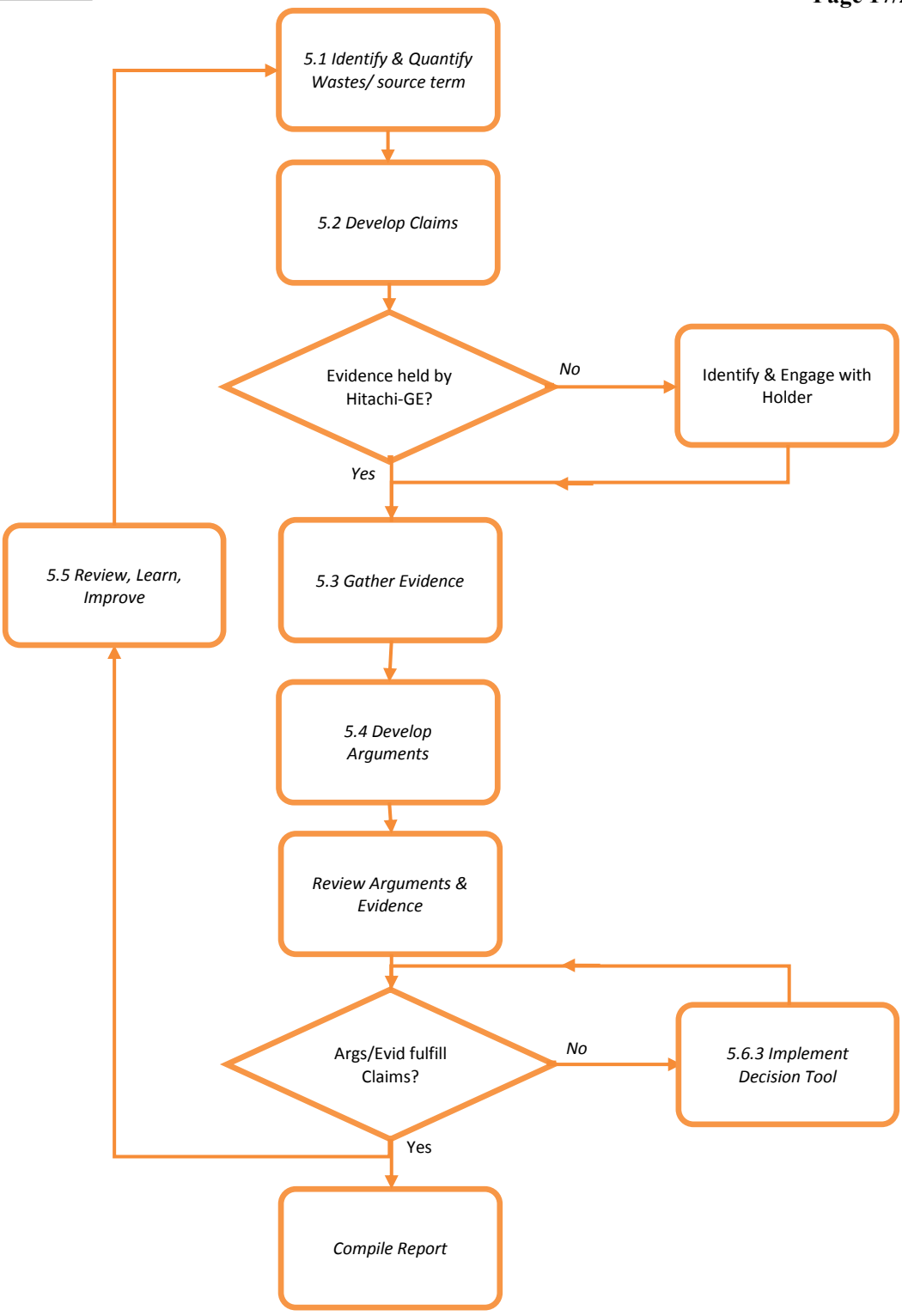

Figure 5-1: Methodology for Demonstrating the Application of BAT

5.1. Identification and Quantification of Radioactive Waste / Source Term

The identification and quantification of radioactive wastes / source term has three objectives:

- Understand how an activity contributes to the generation of radioactive waste;
- Quantify those radioactive wastes that will be generated; and
- Identify pathways to the environment.

This information is then used as the Environmental Optimisation Case develops to determine the extent to which optimisation has already been achieved and what opportunities remain for further optimising the design through the application of BAT. Quantifying the radioactive wastes at the start of the process also supports the 'proportionality principle' and the identification of uncertainties that might impact on the Arguments being developed.

The source term, pathways to the environment, discharges and radioactive wastes will be identified and quantified to support the following:

- Identify where most effort should be expended in further optimising those activities that contribute to the generation of radioactive waste;
- Support the application of the waste hierarchy (prevent, reduce, reuse, recycle and dispose);
- Understand the challenge in terms of management, treatment, potential impact presented by radioactive waste and discharges;
- Determine the potential impacts of radioactive wastes and discharges on members of the public and the environment;
- Correctly design radioactive waste management systems;
- Determine the performance of radioactive waste management systems; and
- Demonstrate control.

The following characteristics of the wastes may be determined:

- Physical;
- Chemical;
- Radiological; and
- Biological.

Where gaps are identified in the Evidence to support the identification and quantification process, these will be identified as uncertainties. These uncertainties, and any associated assumptions, will be assessed to determine their potential impact on Arguments presented within the Claim-Argument-Evidence model and formulate forward actions as required.

5.2. Develop Claims

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.

A Claim is 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.

Sources of information that support the development of Claims are:

- Identification and quantification of radioactive wastes/source term;
- Environmental Permits;
- Other BAT studies; and
- Technical advisors.

An example overview of a Claim-Argument-Evidence model has been provided within Appendix A. This illustrates the overall structure that is used to develop the Claim-Argument-Evidence model and how multiple Arguments are used to validate a single Claim. Appendix B provides a specific example of a Claim and Argument and details the type of Evidence that would be required to substantiate the Argument. The Claim illustrates how the specific conditions of the permit and requirements of the P&ID that are being addressed are referenced and how the context of the Claim should be developed.

5.3. Gathering Evidence

Evidence is information available to support the demonstration that BAT is being applied and is required to:

- Underpin Arguments;
- Allow examination and challenge; and
- Identify key gaps (uncertainties).

This methodology addresses the gathering of Evidence prior to developing the BAT Arguments. This ensures that Arguments are Evidence-based. It is recognised however, that as the case develops the process of gathering Evidence and developing Arguments becomes iterative.

Important considerations when gathering Evidence are:

- Where does it come from?
- How comprehensive is it?
- How applicable is it?
- How reliable is it?

These questions are used to assess the significance of uncertainties identified within the Evidence base and to assess the sensitivity of the Arguments to any assumptions that have been made within the Evidence

base.

The Evidence base provided to substantiate the Arguments can comprise a range of sources of Evidence including:

- Analytical data;
- Research and Development;
- Trials;
- Modelling;
- Reports;
- Records of experience;
- Considered opinion; and
- Output from option assessment studies (if conducted in a manner suitable for use).

In determining when more can be done, and exploring the proportionality Argument, the Evidence base can be complimented with the output from a range of tools and techniques. These tools and techniques can contribute to:

- Decision making (including options selection);
- Reducing uncertainty;
- Substantiating Arguments; and
- Demonstrating performance.

A range of tools and techniques are available, whose output will be appropriate to be used as Evidence when demonstrating the application of BAT. Some of the more commonly used tools and techniques have been listed below:

- Multi-attribute decision analysis;
- Cost benefit analysis;
- Trials; and
- Value engineering.

Other tools and techniques are available. As with all tools and techniques these should be assessed to ensure that they meet the requirements of environmental optimisation and the application of BAT prior to implementation.

5.4. Develop Arguments

Arguments are a series of statements that are required to:

- Demonstrate that the series of Claims are valid;
- Draws the Evidence into a ‘story’; and
- Identify uncertainties and assumptions.

Important considerations for the preparation of Arguments are:

- One or more Argument must be established for each Claim;
- The contribution that each Argument makes to fulfilling the Claim must be determined;
- The Evidence that is important to the Argument must be identified; and
- The impact of uncertainties/assumptions must be described.

Sources of information that can assist in the preparation of Arguments are:

- RGP;
- Reports;
- Discussions and debate;
- Experience; and
- Historical information.

Each Argument shall contain:

- A short description of the context/issue and why it is important to the application of BAT.
- A discussion on how relevant features of the UK ABWR contribute (or not) to delivering environmental performance.
- A statement that clearly articulates what has been achieved.
- Comments on gaps, uncertainties, observations and actions.

An example Argument is provided within Appendix B.

5.5. Review, Learn and Improve

The 'review, learn and improve' process will monitor the ability of this 'Approach to Optimisation' to achieve its intended results, supporting the demonstration that the generic design of the UK ABWR fulfils UK and international expectations with regard to environmental optimisation and the application of BAT. The review process includes self-assessment, independent review and management system review and will enable opportunities for improvement to be identified and implemented where appropriate. The review process has been developed to deliver the following:

- To evaluate the effectiveness of processes in meeting and fulfilling goals, strategies, plans and objectives;
- To determine the adequacy of work performance and leadership;
- To monitor product quality; and
- To identify opportunities for improvement.

The review process incorporates the output from a range of sources including:

- Stakeholder feedback;
- Follow-up actions from previous management reviews;
- Outputs from self-assessments and independent reviews;

- Results delivered and objectives achieved by the organisation and its processes; and
- Lessons learned from other organisations.

5.6. Management of Gaps and Uncertainty

The methodology recognises the iterative nature of design development and acknowledges that there will be gaps and uncertainties associated with Evidence and Arguments. The methodology requires that gaps and uncertainties are identified and their associated impact on the demonstration of BAT is understood. This allows appropriate mitigation and management measures to be put in place to ensure that such measures are delivered at the most appropriate stage of the GDA or site-specific programmes.

5.6.1. Assessing the quality of Evidence

Environmental optimisation and demonstrating the application of BAT relies on Evidence that is:

- Robust;
- Defensible; and
- Demonstrable.

The Evidence that is gathered needs to be reviewed to establish the presence and size of:

- **Gaps** - Information related to a particular subject or design element is incomplete or not available.
- **Uncertainties** - Confidence in using the information for the UK ABWR is low because it is of uncertain provenance; has not been subject to appropriate governance process or is not directly applicable to ABWR technology.

Quality of supporting Evidence can be placed in one of three broad groups presented in order of preference, with the least desirable first:

- **Supposition ('I think'):** Evidence that is based on views and opinions of individuals.
- **Knowledge ('I know'):** Evidence based on individuals' qualifications, expertise and experience.
- **Fact ('I can show'):** Evidence that can be validated and is from a reputable, auditable source.

5.6.2. Determining the impact of gaps and uncertainty on Arguments and Claims

The impact of gaps and uncertainties on Arguments must be determined to ascertain the need for additional work. Key considerations are:

- How important is the Evidence?
- Does the Argument rely on this Evidence?
- Can the other, existing Evidence be used to support the Argument?
- How big is the uncertainty?
- Is information missing?
- Can existing information be interpreted/extrapolated?
- Is expertise missing?

The same approach is adopted for reviewing Claims by considering gaps and uncertainties related to

Arguments.

The tool presented in Figure 5.6.2-1 can be used as a simple guide when determining whether additional Evidence is required. 'Check other Evidence' requires that the current Evidence base should be revisited to determine whether there are opportunities to use existing information by direct reference or extrapolation prior to undertaking additional Evidence gathering.

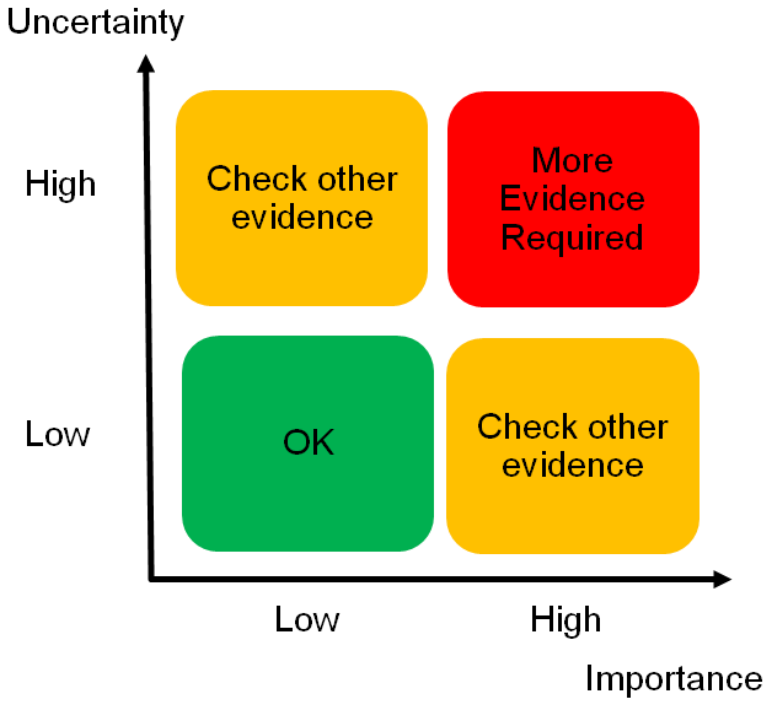

Figure 5.6.2-1: Gap/Uncertainty Tool

5.6.3. The Decision Tool

The decision tool is used to define the scope and timing of additional work that is necessary to fill gaps or address uncertainties. It is presented diagrammatically in Figure 5.6.3-1. The decision tool shall be used by suitably qualified experienced persons either individually or collectively. The outcomes from applying the decision tool shall be recorded and scrutinised in accordance with the project governance arrangements.

What additional Evidence is required?

- Context clearly defined – why we need it
- Clear scope of work – what we need
- Focus on filling gaps or resolving uncertainty – limited to indentified issues

When is the additional Evidence required?

- Required immediately?
- Is it already on the project programme?
- Site specific issue?

A gap or uncertainty that requires assessment using the decision tool can include those associated with a proposed design change. It is also possible that in order to provide the required Evidence to update an

Argument, the decision tool will drive a requirement for a design change.

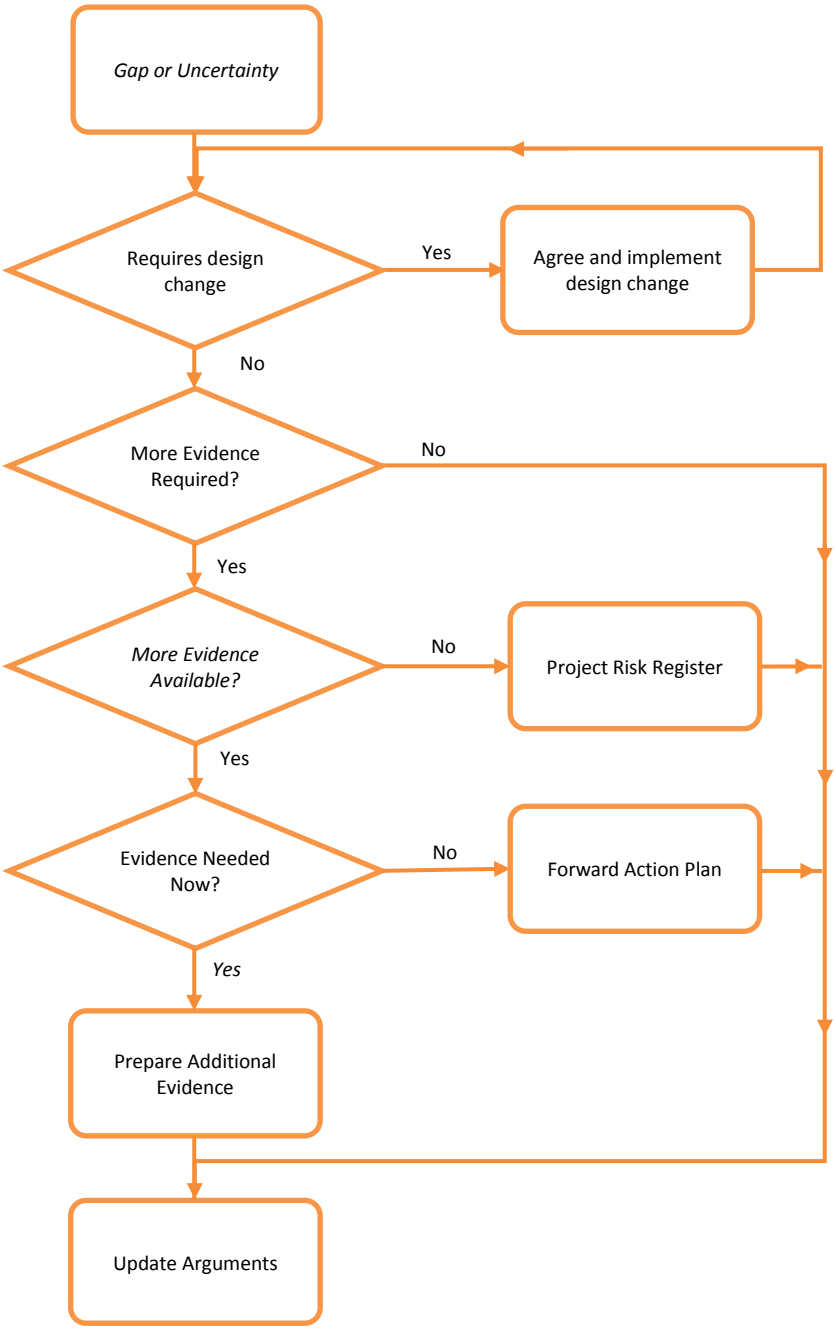

Figure 5.6.3-1: The Decision Tool

5.7. Forward Action Plan

The Forward Action Plan defines the scope and timing of additional work that will be delivered after the production of the Environmental Optimisation Case. The purpose of the Forward Action Plan is to:

- Recognise that not all BAT-related work needs to be done now;
- Identify future tasks that will be delivered at the most appropriate time in the programme;
- Identify the person or function responsible for discharging the action;
- Demonstrate Hitachi-GE's commitment to address identified issues; and
- Help the Environment Agency define Assessment Findings for GDA.

5.8. Proportionality

The Environment Agency has indicated that it will take a proportionate approach, both to the degree of assessment that is required by themselves and operators, as well as to the techniques that they require operators to use to optimise environmental performance. In terms of proportionality the Environment Agency's guidance (4) provides the following:

> *'...the point at which detriments* [expressed as time, trouble and money] *from implementing further techniques becomes grossly disproportionate to the benefits* [expressed in reduction in dose to members of the public] *gained.*'

Information obtained during the Evidence gathering process must therefore be of the type and level of detail that supports the determination of proportionality. Key considerations are:

- What has been done to date to address the issue under consideration?
- How much time, trouble and money have been invested to date?
- What benefit has been achieved [in terms of reduction in dose to members of the public]?
- What more can be done?
- What additional time, trouble and money would need to be invested to implement further improvement?
- What additional benefits would be achieved?
- How different is the return on investment for the improvement when compared to the original investment?

5.9. Reporting

An Environmental Optimisation Case provides a written account of how an undertaking demonstrates the application of BAT at a given time. The final Environmental Optimisation Case must capture the decision making process that leads to any conclusions drawn and include a robust consideration of the impact of any uncertainties. At predefined points of a project this 'Case' is then formulated into the 'Demonstration of BAT' report. The iterative nature of environmental optimisation is recognised and addressed within this methodology through the review, learn and improve process. This ensures that opportunities to continue to further optimise environmental performance can be realised throughout the UK ABWR's life cycle.

5.10. Change management

The link between the optimised design and the demonstration of BAT presented within the Claim-Argument-Evidence model will be managed through the change management process. Both the Environmental Optimisation Case and the change management process are owned by the Hitachi-GE design authority. This will ensure that BAT Arguments, the Environmentally Sensitive Equipment (ESE) that delivers the operational performance demanded by the BAT Arguments, management controls and the management system are communicated to designers, operators and managers. Any changes to the design are managed through the change management process to ensure that any impact on the strength of BAT Arguments can be appropriately assessed.

Any proposed change to the configured design will be managed through Hitachi-GE's change management process. The change will need to be assessed to determine the extent it impacts on the BAT Arguments. Each change will be assessed on the following basis:

> **Positive or neutral impact**: Small assessment may be required and recorded as part of the change management process. As part of the periodic review of the Environmental Optimisation Case this change will be incorporated within the case with the driver (e.g. safety, operability, environment, etc) for the change clearly stated.
>
> **Negative impact:** Detailed assessment of the change and update of the Environmental Optimisation Case required.

As part of the change management process it is recognised that any proposed change (positive, neutral or negative) provides an opportunity to revisit key BAT Arguments and to determine if the requirement for a change provides an opportunity for further environmental optimisation beyond that delivered by the initial approach. Any opportunities that are identified will be formally communicated to the individual/team instigating the proposed change through the change management process.

6. Conclusion

This methodology has been used by Hitachi-GE to develop the Claims and accompanying Arguments that are presented in the 'Demonstration of BAT' (2) (also submitted for the Environment Agency's initial assessment). The Evidence that will support these Claims and Arguments will be supplied in the GDA Step 2 submission.

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

The demonstration of BAT will be an ongoing process that feeds back to the design; if at the end of the process any areas of insufficient Evidence remain, design changes may be made to address the requirement.

Appendix A: Example from the Claim-Argument-Evidence Model

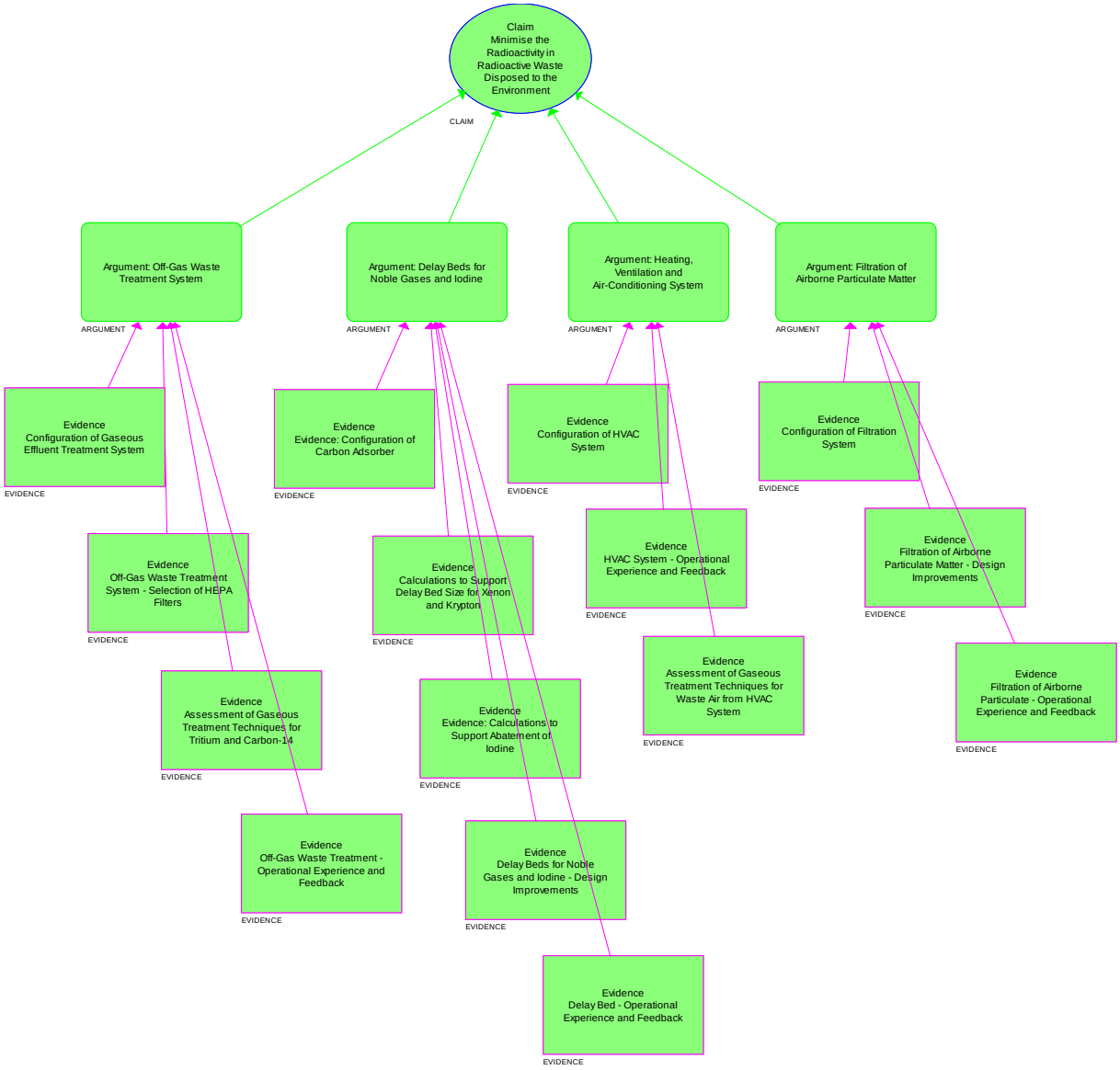

Figure A.1: Example Claim and underpinning Argument and Evidence structure

Appendix B: Example Claim-Argument-Evidence

Example Claim: 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 (5) and the relevant requirements of the P&ID (1) as provided below:

- Permit 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.'
- Permit 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 requirement 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 a Charcoal Adsorber within the Off-Gas system to abate short-lived fission products.
- An HVAC system that prevents the uncontrolled discharge of radioactive substances.
- 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 this Claim, the REPs have been taken into account. The following REPs are considered to be specifically relevant to this Claim:

- **Principle ENDP15** 'BAT should be used to prevent and/or minimise releases of radioactive substances to the environment, either under routine or accident conditions.'
- **Principle ENDP16** 'BAT 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.'

Example Argument: Off-Gas Charcoal Adsorber for Noble Gases

Low concentrations of fission products such as noble gases will be present in the off-gas from the reactor. 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 whose purpose is to retain the fission products for a defined period during which they undergo radioactive decay. The chemical properties of the fission products and activated charcoal define the rate at which the fission products are adsorbed 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.

Evolution of the (A)BWR design has introduced a number of improvements to the system for retaining noble gases. 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. 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 that would be discharged is very small.

Example Evidence

To substantiate the Argument that has been presented it is expected that a variety of Evidence sources will be used. This Evidence will be summarised and linked directly to the part of the Argument that it contributes to. As an example the substantiation of the delay period within the Off-Gas Charcoal Adsorber will be based on assessment of the release of radioactive noble gases to site environs. Costs associated with increasing the size or number of the charcoal adsorber units would also be provided to support the Argument that it is grossly disproportionate to further increase the delay period.