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UK ABWR

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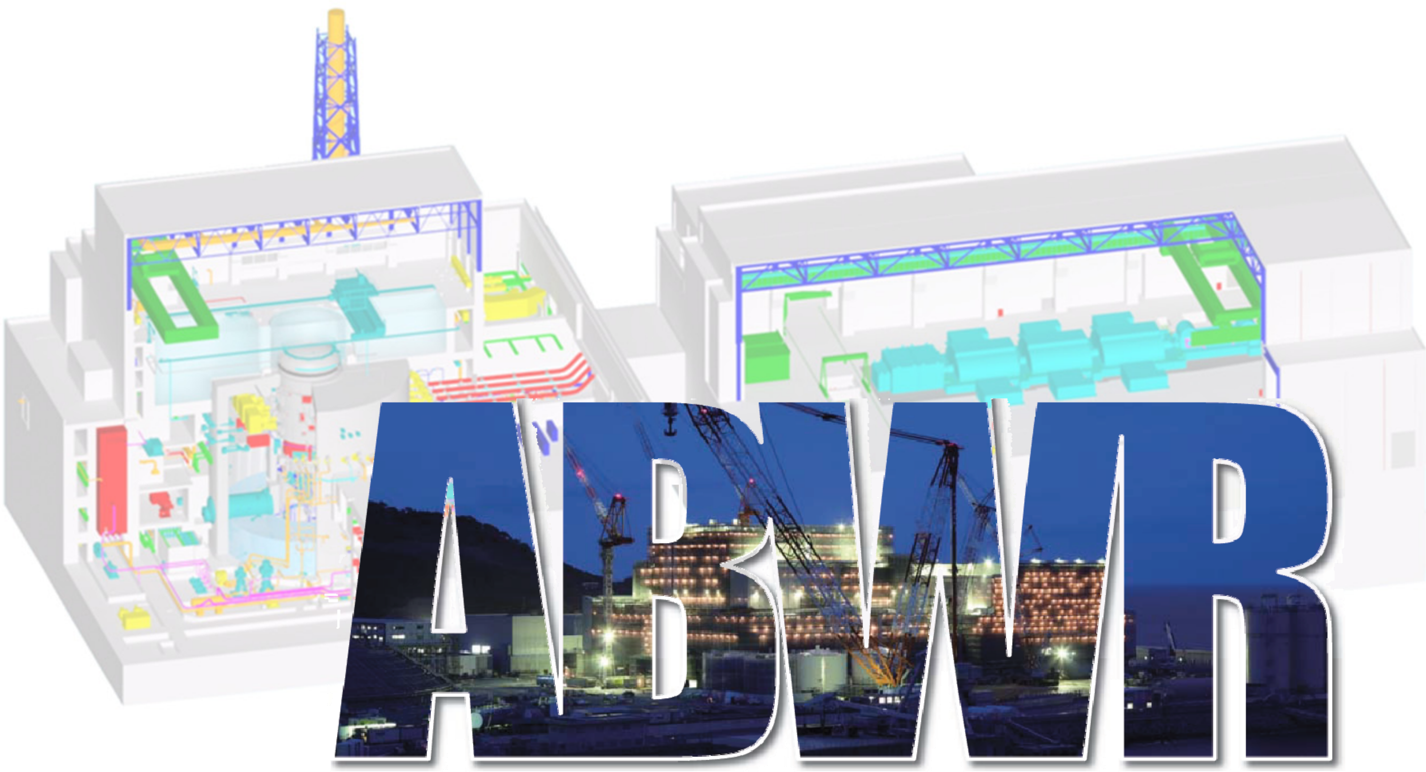
Other Environmental Regulations



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1. Acronyms

AA	Annual Average
ABWR	Advanced Boiling Water Reactor
B/B	Back-up Building
BAA	British Airport Authority
BAC	Bead Activated Carbon
BAT	Best Available Technique(s)
BBG	Back-up Building Generator
BREF	BAT Reference Document
Bq/y	Becquerel(s) per year
CA	Competent Authority
CAD	Controlled Area Drain
CAS	Chemical Abstracts Service
CCGT	Combined Cycle Gas Turbine
CD	Condensate Demineraliser
CEMS	Continuous Emissions Monitoring System
CHP	Combined Heat and Power Plant
Cl^-	Chloride ion
CLP	European Regulation (EC) No 1272/2008 on classification, labelling and packaging of substances and mixtures
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COD	Chemical Oxygen Demand
COMAH	Control of Major Accident Hazards
CONW	Concentrated Waste System
CSG	Combustion Sector Guidance Note
CST	Condensate Storage Tank
CUW	Reactor Water Clean-up System
CW	Circulating Water System
D/W	Dry Well
DAG	Diverse Additional Generator
DC	Discharge Concentration
DECC	Department of Energy and Climate Change

DEFRA	Department for Environment, Food and Rural Affairs
DF	Decontamination Factor
DHN	District Heating Networks
DTA	Direct Toxicity Assessment
DW	Domestic Water
EA	Environment Agency
EAL	Environment Assessment Level
EC	European Commission
ECCS	Emergency Core Cooling System
ECU	electronic engine management system
EDG	Emergency Diesel Generator
EMAS	Eco Management and Audit Scheme
EMS	Environmental Management System
EPA	Environmental Protection Agency
EPR/EPR2016	Environmental Permitting (England and Wales) Regulations 2016
EQS	Environment Quality Standard
ETS	Emissions Trading Scheme
EU	European Union
FLSS	Flooding System of Specific Safety Facility
FPC	Fuel Pool Cooling and Clean-up System
GAC	Granular Activated Carbon
GDA	Generic Design Assessment
GEP	Generic Environmental Permit
GT	Gas Turbine
GWh	Gigawatt Hour
H1	Environment Agency’s Horizontal Guidance Note H1 Environmental Risk Assessment and its annexes
H2	Environment Agency’s Horizontal Guidance Note IPPC H2 Energy Efficiency
Ha	Hectare
HB/B	House Boiler Building
HCEP	How to comply with your environmental permit
HCW	High Chemical impurities Waste
HECW	HVAC Emergency Cooling Water System
HMIP	Her Majesty’s Inspectorate of Pollution
HNCW	HVAC Normal Cooling Water System
HSA	Hazardous Substances Authority

HSD	Hot Shower Drain
HSE	Health and Safety Executive (UK)
HVAC	Heating Ventilating and Air Conditioning System
IA	Instrument Air System
IAEA	International Atomic Energy Agency
IBC	Intermediate Bulk Container
IED	Industrial Emissions Directive
IHT	Inter-seasonal Heat Transfer
IPPC	Integrated Pollution Prevention and Control
LCW	Low Chemical impurities Waste
LD	Laundry Drain
LLE	Liquid-liquid Extraction
LLW	Low Level Waste
LNB	Low-NO_x Burner
LOCA	Loss of Coolant Accident
LOOP	Loss of Off-site Power
LT	Lower Tier (COMAH category)
LWMS	Liquid Waste Management System
M&T	Monitoring and Targeting
MAC	Maximum Allowable Concentration
MAPP	Major Accident Prevention Policy
MATTE	Major Accident to the Environment
MCERTS	Monitoring and Certification Scheme
MCR	Maximum Continuous Rating
mg/l	Milligramme per litre
MMR	Monitoring and Reporting Regulation
MW	Megawatt
NAB	National Accreditation Body
NO	Nitric Oxide
NO_2	Nitrogen Dioxide
NO_x	Oxides of Nitrogen (NO and NO_2)
NOD	Non-radioactive Oil Drain
N_2O	Nitrous Oxide
NPP	Nuclear Power Plant
NRW	Natural Resources Wales

NSD	Non-radioactive Storm Drain
OCGT	Open Cycle Gas Turbine
P&D	Plumbing and Drainage System
P&ID	Process and Information Document for Generic Assessment of Candidate Nuclear Power Plant Design
PC	Process Contribution
PEC	Predicted Environmental Concentration
PM	Particulate matter
PNEC	Predicted No Effect Concentration
ppb	Parts per billion
PPG	Pollution Prevention Guide
ppm	Parts per million
PPM	Pollution Prevention Measures
PWTF	Purified Water Treatment Facility
RAS	Recirculation Aquaculture Systems
R/B	Reactor Building
RCW	Reactor Building Cooling Water System
RHR	Residual Heat Removal System
RSR	Radioactive Substances Regulation
RSW	Reactor Building Service Water System
Rw/B	Radioactive Waste Building
S/B	Service Building
SA	Station Service Air System
SCR	Selective Catalytic Reduction
SDS	Safety Data Sheet
SE	Single Exposure
SFP	Spent Fuel Storage Pool
SLC	Standby Liquid Control System
SLD	Standby Liquid Drain
SMS	Safety Management System
SO_2	Sulphur Dioxide
SO_4^{2-}	Sulphate ion
SO_x	Oxides of Sulphur
STOT	Specific Target Organ Toxicity
SWSD	Service Water Storm Drain
T/B	Turbine Building

TCW	Turbine Building Cooling Water System
TGN	Technical Guidance Note
TOC	Total Organic Carbon
TRL	Transport Research Laboratory
TRO	Total Residual Oxidants
TSW	Turbine Building Service Water System
UK	United Kingdom
UK ABWR	United Kingdom Advanced Boiling Water Reactor
UKAS	UK Accreditation Scheme
ULSD	Ultra Low Sulphur Diesel
UNECE	United Nations Economic Commission for Europe
US	United States
USA	United States of America
USEPA	United States Environmental Protection Agency
UT	Upper Tier (COMAH category)
VOC	Volatile Organic Compounds
VSD	Variable Speed Drives
WFD	Water Framework Directive
WHEP	Waste Heat Energy Parks
µg/l	Microgrammes per litre
µS/m	Microsiemens per metre

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3. Introduction

The Environment Agency (EA) has identified the information it requires to assess the environmental impacts of the UK Advanced Boiling Water Reactor (ABWR) at a generic site in the Process and Information Document for the Generic Assessment of Candidate Nuclear Power Plant Designs (P&ID) [Ref-1].

Table 1, part 8 of the P&ID details the information Hitachi-GE is required to provide regarding the applicability and impact of other environmental regulations on the design and the generic site. The areas in question relate to the non-radioactive regulations, specifically:

- Water use and abstraction.
- Discharges to surface waters.
- Discharges to groundwater.
- Operation of installations (combustion plant and incinerators).
- Substances subject to the Control of Major Accident Hazards (COMAH) Regulations.
- Fluorinated greenhouse gases and ozone-depleting substances.

Hitachi-GE's Step 1b Other Environmental submission summarised the applicability of these five areas except the "Fluorinated greenhouse gases and ozone-depleting substances", which has been added from version 2 of the P&ID, to the UK ABWR and set the scope of the information to be provided by Hitachi-GE as part of the Generic Design Assessment (GDA) process.

These areas including additional item of "Fluorinated greenhouse gases and ozone-depleting substances" have been developed through the GDA process. This document presents the sum of the information available at the end of the GDA process for the Other Environmental aspects. The report has been sub-divided into six sections, each addressing one of the six areas detailed in the P&ID requirements, as follows:

- Water use and abstraction (Section 4).
- Discharges to surface waters (Section 5).
- Discharges to groundwater (Section 6).
- Operation of installations (combustion plant and incinerators) (Section 7).
- Substances subject to the COMAH Regulations (Section 8).
- Fluorinated greenhouse gases and ozone-depleting substances. (Section 9)

The conclusions from the six sections are summarised in a separate section (Section 10) at the end of the report.

4. Water Use and Abstraction

The purpose of this section of the report is to address the EA's P&ID requirements [Ref-1] with regard to water use and abstraction requirements.

Some of the P&ID requirements for water use and abstraction will be addressed at the site-specific stage as they are dependent on aspects specific to the characteristics of the chosen site.

4.1 P&ID Requirements

The EA has identified the information it requires to carry out the GDA in the P&ID [Ref-1]. The P&ID requirements relating to water use and abstraction are reproduced below:

'Provide details and estimates of freshwater requirements for the design.

Provide details and estimates of cooling water requirements for the design relevant to the generic site. Include consideration of:

- *seawater or river water abstraction;*
- *use of conventional cooling towers or hybrid cooling towers;*
- *abstraction inlet fish deterrent schemes; and*
- *fish return systems'*

The information to address these P&ID requirements is presented in three sections.

- **Freshwater requirements** (Section 4.3) - describes the freshwater requirements for the UK ABWR generic design at the generic site.
- **Cooling water system requirements** (Section 4.4) - describes the cooling water requirements for the UK ABWR generic design at the generic site.
- **Fish deterrent and fish return systems** (Section 4.5) - describes the fish deterrent and return systems that could be used for the UK ABWR.

4.2 Regulatory Context

There are two main areas of legislative requirements relevant to this section of the P&ID:

- Water abstraction – regulated under the Water Resources Act 1991 (as amended) [Ref-2];
- The Eels (England and Wales) Regulations 2009 [Ref-3].

Water abstraction from controlled waters is regulated under the Water Resources Act 1991 (as amended) [Ref-2], Part II, Chapter II, and the Water Resources (Abstraction & Impounding) Regulations 2006 [Ref-4]. A licence is required from the EA (or Natural Resources Wales (NRW) in Wales) to impound water or to abstract over 20 m^3/day of water from a river or stream, reservoir, lake or pond, canal, spring, underground source or estuary, bay or arm of the sea. Abstraction licensing is a site-specific issue.

The Eels (England and Wales) Regulations 2009 implement EC Council Regulation (1100/2007) (the EC Eel Regulation) (Eels Regulations) [Ref-5]. This regulation requires the operator of an abstraction or water diversion of more than 20 m^3/day, or any discharge to a channel, bed or sea (out to 6 nautical miles) to screen it to prevent the entrainment of eels. Since the 1st January 2015, it has become an offence not to have a screen on any such intake or outfall, unless the EA/NRW has specifically issued notice to exempt the requirement.

In addition, the EA/NRW can require the provision of fish passes and screens for the protection of salmon and migratory trout (sea trout or sewin) under the Salmon and Freshwater Fisheries Act 1975 [Ref-6].

4.3 Freshwater Requirements

The GDA is based on the assumption that all freshwater requirements will be supplied by the local water company and that freshwater abstraction, and an abstraction license, will not be required. This does not preclude the consideration of other freshwater supply options for specific sites (depending on the availability of local sources of freshwater).

Freshwater will be used for drinking, washing and showering by personnel, and within the process as part of the Domestic Water System. The freshwater required for these processes will depend on the number of workers present, and will therefore be addressed at the site-specific stage. Freshwater will also be used for firefighting purposes (Section 4.3.1).

The main processes requiring freshwater within the UK ABWR are:

- Concentration Tank for Drained Water Treatment - (Normal / Shutdown / Outage): 24 m^3/day (continuous); Emergency condition: 0 m^3/day.
- Hydrochloric Acid Scrubber for Water Purifying Equipment - (Normal / Shutdown / Outage): 24 m^3/day (continuous); Emergency condition: 0 m^3/day.
- Drain Treatment Device Sludge Pump - (Normal / Shutdown / Outage): 4 m^3/day (continuous); Emergency condition: 0 m^3/day.
- Washing Machine - (Normal / Shutdown / Outage): 40 m^3/day (continuous); Emergency condition: 0 m^3/day.
- Circulation Pump for Condenser Ball Cleaning Device - (Normal / Shutdown): 7.2 m^3/day (continuous); Outage / Emergency condition: 0 m^3/day.
- Insulator Washing Tank (for washing insulators to remove potential contaminants) - (Normal / Shutdown / Outage): 720 m^3/day (intermittent); Emergency condition: 0 m^3/day.
- Main Condenser - Normal operation / Emergency condition: 0 m^3/day; Shutdown / Outage: 160 m^3/day (outage use is for washing the condenser).
- Reactor Building Cooling Water System (RCW) Heat Exchanger – Normal: 79m^3/week; Shutdown / Emergency condition: 0 m^3/day; Outage: 79 m^3/day.
- Turbine Building Cooling Water System (TCW) Heat Exchanger – Normal: 39m^3 x four times/year; Shutdown / Emergency condition: 0 m^3/day; Outage: 32 m^3/day.
- Purified Water Treatment Facility (PWTF).

In summary therefore, in operation under normal load the freshwater consumption of the UK ABWR is 99.2 m^3/day, rising to a maximum of 819.2 m^3/day when incorporating the activation of intermittent systems. In outage the freshwater consumption is 252 m^3/day, rising to a maximum of 1,083 m^3/day. These figures do not include the requirement of the PWTF (see below). More detailed information on the water usage within the UK ABWR is presented in Table 1 [Ref-8].

Freshwater is required by the PWTF to produce purified water for various uses as part of the purified water system. The purified water is stored in the Purified Water Storage Tank. The purified water system pump transports the purified water to the Condensate Storage Tank (CST), or for use elsewhere within the UK ABWR [Ref-9]. Purified water usages include the following processes:

- Reactor water (refill of primary circuit water loss, clean-up).
- Auxiliary boiler water.
- Boronated water in the Standby Liquid Control System (SLC).

The PWTF is estimated to require 900 m^3/day when operating at maximum rate.

In addition the ABWR will have a back-up water supply on site, comprising ten water storage tanks, each with a storage capacity of 1,000 m^3. It is expected that the water stored in these tanks will be purified water. The water in each tank will be stored for 15 years, with the contents of one tank replaced during every 18 month outage period.

4.3.1 Firewater

Firewater may be supplied from two Domestic Water (DW) tanks. It can be assumed that two tanks would be provided to ensure redundancy of supply.

The DW tanks will be used commonly as the source for domestic and firefighting water. In order to ensure the firewater demand (1,000 m^3) is always available, the connections for DW use and firewater use will be installed at different levels within each tank, so as to provide a dedicated 'reserve' at the bottom of the tank for use as firefighting water.

4.4 Cooling Water System Requirements

4.4.1 Selection of Cooling Water System

The GDA is based on the assumptions that the site is coastal [Ref-10] and that a once-through seawater cooling system will be used. In general, the use of once through cooling systems is considered as the Best Available Technique (BAT) for a coastal location [Ref-11].

The selection of once-through seawater cooling at the site-specific stage does not preclude the consideration of other cooling water system options, and the exact details of the cooling system will be defined at the site-specific permitting stage. Potential cooling options that could be considered as the alternative to the once-through seawater cooling system identified for the generic site, include:

- Once-through cooling using water from an estuary, river, or lake as the heat sink.
- Once-through cooling using cooling towers to cool water before discharge to sea, estuary, river, or lake.
- Recirculation system using natural draft cooling towers.
- Recirculation system using mechanical draft cooling towers.
- Closed-circuit dry air cooled systems.
- Closed-circuit wet cooling.
- Hybrid wet/dry cooling systems (closed or open circuit).

These options are not considered further within the GDA submission.

4.4.2 Description of Cooling Water Systems and Water Use

The UK ABWR will use seawater for once-through cooling in the main steam condenser and for cooling of other reactor and turbine components. The cooling water flow rate is based on a 12°C increase of the intake water temperature at the point of discharge.

The seawater cooling systems of the ABWR can be broken down into three systems, namely the Circulating Water System (CW), the Turbine Building Service Water System (TSW), and the Reactor Building Service Water System (RSW).

The design of the CW, TSW and RSW systems will include control measures to prevent fouling (physical, chemical, biological and mechanical). The control measures selected will depend in part on the characteristics of the receiving marine environment and will therefore be finalised at the site-specific stage. The three once-through systems are described further in the following bullet points:

- CW - this system supplies seawater into the condenser tubes as cooling water [Ref-12]. The system runs continuously during the generation of power, including during start-up and shutdown. Under normal operation the intake rate to the CW system is 184,800 m^3/h. Under outage conditions the rate of intake will be between 0 and 184,800 m^3/h.
- TSW - the purpose of this system is to supply seawater to cool and remove heat from the Turbine Building Cooling Water system (TCW), through the TCW heat exchanger [Ref-13]. The TCW system is a closed loop system [Ref-14] supplying cooling water to the equipment that contains non-radioactive fluid in the turbine building [Ref-13]. The only interaction between the TCW and TSW systems is the transfer of heat via the heat exchanger. There is no mixing of the water between the TSW and TCW systems. No other materials or contaminants are transferred between the cooling water and service water systems. Under normal operation the seawater intake rate to the TSW system is approximately 7,400 m^3/h. Under outage conditions the intake rate will be between 3,700 and 7,400 m^3/h approximately. (The intake rate of approximately 3,700 m^3/h is based on only one TSW pump operating).
- RSW - the purpose of this system is to supply seawater to cool and remove heat from the Reactor Building Cooling Water system (RCW), through the RCW heat exchanger [Ref-13]. The RCW system is a closed loop system [Ref-14] supplying cooling water to the equipment in the reactor and radioactive waste treatment buildings, and the equipment that contains radioactive fluid in the turbine building [Ref-13]. The only interaction between the RCW and RSW system is the transfer of heat via the heat exchanger. There is no mixing of the water between the RSW and RCW systems. No other materials or contaminants are transferred between the cooling water and service water systems. Under normal operation the rate of water intake to the RSW system is approx. 10,800 m^3/h. In shutdown operation and under abnormal/emergency conditions the intake rate will be approx. 16,200 m^3/h. Shutdown operation occurs after core shutdown, when the core is being cooled. During this period the intake rate will decrease to 5,400 m^3/h in accordance with the decrease in core heat load.

Table 4.4-1: Discharges from CW, TSW and RSW in routine operation and outage

Cooling water system	Volume of seawater discharged	
	Normal operation	Lowest discharge during outage
Circulating water (CW)	184,800 m^3/h	0
Turbine Building service water (TSW)	7,400 m^3/h	3,700 m^3/h
Reactor Building service water (RSW)	10,800 m^3/h	5,400 m^3/h
Total	**203,000 m^3/h**	**9,100 m^3/h**

Two designs for the TCW and RCW heat exchangers are included at generic design stage. Final decisions on the heat exchangers to be used in the UK ABWR will be made at the site-specific stage:

- Shell and tube type heat exchanger – aluminium and brass construction. Requires ferrous ion injection to prevent corrosion within the tubes of the heat exchanger. Does not normally require low level dosing with biocide to prevent biofouling within the heat exchanger, but this can be undertaken if site specific parameters require it. Biocide dosing of the shell and tube type heat exchanger has therefore not been addressed further at GDA stage.

- Plate type heat exchanger – titanium construction. Does not require ferrous ion injection. The narrow flow channel geometry of the plate type heat exchanger means that continuous low level dosing with biocide is required to prevent biofouling within the heat exchanger.

It should be noted that the RSW flow rate can be reviewed to be smaller according to a plan thermal balance. However, the change of flow rate will be limited and then a consequence to the result of assessment is expected to be negligible.

4.4.2.1 Ferrous Ion Dosing

As described above, the shell and tube type heat exchangers will require dosing with a supply of ferrous ions to prevent corrosion within the tubes of the heat exchanger. Ferrous ions will be produced from the electrolysis of iron, and then injected into the heat exchanger. This process is hereafter referred to as 'ferrous ion dosing' or 'ferrous ion injection'. It is only required for the shell and tube type heat exchanger, and does not apply for the plate type heat exchanger.

The TSW and RSW systems are dosed with ferrous ions to prevent corrosion within the tubes of the heat exchangers (shell and tube type) that provide cooling of the TCW and RCW systems [Ref-13]. Dosing is a continuous process, with the electrode plate changed periodically. Following dosing, an iron oxide layer is formed on the inner surface of the tubing:

- Commissioning – ferrous ions added continuously over a period of three months to establish the iron oxide coating within the heat exchanger tubes. The injection period can be extended if the formation of iron oxide coating is not sufficient after the determined period. Injection is undertaken to achieve a concentration of 0.03 ppm in the heat exchangers.
- Operation – ferrous ions added continuously to achieve a concentration of 0.01 ppm in the heat exchangers. Continuous dosing is undertaken to maintain the iron oxide coating within the heat exchanger tubes.
- Maintenance (cleaning of the heat exchanger tubes) – following cleaning of the tubes, ferrous ions are added continuously over a period of one month to achieve a concentration of 0.03 ppm in the heat exchangers. The injection period can be extended if the formation of iron oxide coating is not sufficient after the determined period.

There is no dosing of the CW system with ferrous ions [Ref-13].

4.4.3 Seawater Intake (and Outfall)

The seawater inlet and outlet structures for the system will need to be sited and designed to reduce the potential for sediment mobilisation and scour on the sea bed, and to be sited to minimise impact on surrounding habitats and species. These factors are site-specific and will be addressed at the site-specific permitting stage.

Regardless of location, certain measures will be considered with the site-specific design, for example the seawater intake will be screened to remove debris.

The seawater outfall and cooling water discharge are considered further in Section 5.3.1.

4.5 Fish Deterrent and Fish Return Systems

Large water intakes can entrain fish and other marine organisms. These may be killed, or suffer physical damage, as they pass through the system. Inlet structures are usually protected with grills or screens to prevent the entrainment of material into the cooling systems, where it could cause mechanical damage and block condenser tubes. However, fish may become pressed against screens and killed or damaged (an effect that is known as impingement). Evidence suggests that fish entrainment and impingement particularly affects fish larvae and young fish.

Fish entrainment and impingement is a highly complex matter [Ref-11] that varies with locality, and depends on the interplay of numerous factors, including the chemical and physical nature of the water body, the intake requirements of the facility, climatic conditions, and biology of the area [Ref-15]. A number of techniques have been developed and applied by industry to prevent or reduce the entrainment and impingement of fish in large cooling water inlets, and reduce their mortality. The BAT Reference Document (BREF) [Ref-11] notes that the optimum solution must be evaluated on a site-specific basis, and further states that no particular techniques to deter and/or protect fish can yet be identified as BAT. The US Environmental Protection Agency (EPA) guidance document [Ref-15] echoes this assessment, and goes on to state that one or more fish deterrent technologies can be used to provide significant impingement and entrainment protection at most sites.

As the design of any fish deterrent/protection scheme will depend on site-specific factors, it is not possible to define a scheme design at this stage and full design of the system will be considered at the site-specific permitting stage. At this stage however, a number of options can be considered and taken forward to the full site-specific options assessment and selection. Measures that may be adopted as part of the system to reduce fish impingement and entrainment include:

- Design of the inlet structure to minimise intake velocities.
- Location of the inlet structure.
- Use of screens and fish return systems.
- Physical barriers.
- Behavioural barriers.

These measures are briefly described below. Any approach to the water inlet system and measures to reduce fish entrainment and impingement will be compliant with the requirements of the Eels Regulations [Ref-3], as appropriate.

4.5.1 Design of the Inlet Structure to Minimise Intake Velocities

Limiting the speed of water inflow through careful design can allow fish to escape and prevent entrainment and impingement. However, there is some evidence to suggest that limiting intake velocity may have a limited efficacy as some entrained fish allow themselves to drift even when they are able to swim fast enough to escape the inlet [Ref-11].

4.5.2 Location of the Inlet Structure

Consideration should be given to avoidance of critical areas, for example spawning grounds, fish nurseries and migration routes.

4.5.3 Use of Screens and Fish Return Systems

Physical screens are used to prevent the intake of materials and debris, including fish, in the cooling water, but have the effect of causing fish impingement. Various types of screen are available, such as drum screens, travelling band screens, and bar screens (for upstream coarse screening). Each screen type is used in conjunction with other techniques to limit damage to the fish:

- Drum screens – when used to screen debris from the water intake, high pressure sprays are used to remove the debris from the screens. However, this is particularly damaging to fish [Ref-15]. Implementing a low pressure spray in advance of the high pressure spray may wash the fish off the screen in a less damaging way.
- Travelling band screens - can be modified so that impinged fish are collected from the screen surface in fish buckets or baskets, and transported to a fish return system. A variation on modified travelling screens is to use fine mesh screens, which have mesh sizes below 5 mm.

- Bar screens - the intake velocity should be limited in front of the bar to prevent impingement.

The selection of appropriate screens will be considered at the site-specific design stage.

4.5.4 Physical Barriers (other than Screens)

Physical fish barriers can be used in front of, or around, cooling water inlets. They can take the form of fish nets, microfiltration barriers, or porous dikes.

Barrier fish nets form a physical barrier to prevent fish becoming entrained in cooling water inlets; they have to be sized to minimise fish becoming stuck in the meshes [Ref-15]. They are most commonly used seasonally, to provide barriers to migratory fish.

Microfilter barriers are fine barriers that are designed to filter out organisms. In order to ensure a reasonable through-flow they are placed at a distance from the inlet to ensure a large surface area.

Porous dikes (also termed leaky dams) are structures resembling breakwaters that surround a cooling water inlet. The dike is constructed from cobbles or gravel that permits the through-flow of water, but acts as a physical and behavioural barrier to aquatic organisms.

4.5.5 Behavioural Barriers

There are a variety of behavioural barriers that can be used to divert fish away from inlets and screens. The main types of behavioural barriers that could be considered for fish deterrent schemes are light and sound barriers. The use of both measures may supplement the effect of the other.

5. Water Discharge

The purpose of this section of the report is to address the EA's P&ID requirements [Ref-1] with regard to discharges from the UK ABWR to surface waters. In summary, this section describes the aqueous waste streams that arise, where they will be discharged to, and how they will be managed in order to minimise the potential environmental impact posed.

Some of the P&ID requirements for discharges to surface waters will be addressed at the site-specific stage as they are dependent on aspects specific to the environment and topography of the chosen site.

5.1 P&ID Requirements

The EA has identified the information it requires to carry out the GDA in the P&ID [Ref-1]. The P&ID requirements relating to discharges to surface waters are reproduced below:

> *'Provide a description of how aqueous waste streams will arise, be managed and be disposed of throughout the facility's lifecycle. Including:*
>
> - *Sources and quantities of contaminants (including disinfectant and biocides), highlighting any priority substances (as specified in the 'Priority Substances' Directive (EU, 2008)).*
> - *Identification of the effluent and surface water run-off streams contributing to the overall discharge and how they are controlled.*
> - *Potential options and associated environmental impact for disposal of each individual effluent stream.*
> - *The means of control in the event of detection of unplanned radioactive or other contamination of the discharge.*
> - *Options for beneficial use of the waste heat produced.*
> - *Environmental impact of thermal discharges.'*

The information to address these P&ID requirements is presented below in three sections.

- **Effluent characterisation** (Section 5.3) - describes the key aqueous effluent streams generated from the UK ABWR Nuclear Power Plant (NPP) at the generic site, and the information available on the potential non-radioactive contaminants present.
- **Effluent treatment and assessment of the impacts of discharged effluents** (Section 5.4) - describes the planned management or treatment options for each of the effluent waste streams to mitigate environmental impacts that may occur. This includes the design of the effluent treatment system to manage unplanned releases.
- **Identification of options for the beneficial use of the waste heat produced** (Section 5.5) - reviews the potential options for the beneficial use of power cycle waste heat. The option chosen will be determined (in part) on issues specific to the selected site. Therefore, no final selection of the option to be used has been made at this GDA stage.

5.1.1 Thermal Discharges

In order to assess the environmental impact of the thermal plume generated by the cooling water discharge, accurate information is required on the behaviour of the receiving surface water and how this interacts with the various substances discharged. This can only be achieved using computational modelling supported by localised monitoring data from the specific site.

It is therefore proposed that no thermal dispersion modelling is undertaken at the GDA stage, on the basis that the assessment of the impact of thermal dispersion is site-specific and, as a consequence, the thermal impact of discharges will be assessed in detail at the site-specific permitting stage using site-specific dispersion modelling.

Information to input into the thermal dispersion modelling, such as the temperature uplift of the cooling water is presented at the GDA stage and has been included as part of the review of the aqueous effluent streams in Section 5.3.1.

5.2 Regulatory Context

Discharges of trade effluent (which encompasses all non-radioactive effluents generated at the generic site) to controlled waters (which include coastal waters out to the territorial limit) require a permit under the Environmental Permitting (England and Wales) Regulations 2010 (SI 2010 No.675), as amended [Ref-16].

The NPP operator will have to apply for an Environmental Permit at the site-specific permit application stage. The permit application will include information on the source of the effluent, identify the flow rate and contaminants in the effluent (including heat) and assess the impact of the releases on the receiving environment, including specific assessment of the impact on EU Habitats sites and nationally designated sites and species.

At the GDA stage, the P&ID requires the requesting party to provide information on proposed discharges to surface water in order to demonstrate that the UK ABWR can operate within the requirements of the UK regulatory requirements. The approach undertaken by Hitachi-GE draws upon the relevant parts of the EA's guidance [Ref-17].

5.3 Effluent Characterisation

Aqueous waste streams that could be generated at the UK ABWR licensed site are divided into four main categories, namely the discharges from the cooling water systems, the drainage networks from non-radioactive areas, the drainage from radioactive areas (via the Liquid Waste Management System (LWMS)), and run-off from rainfall onto the buildings and ground within the nuclear licensed site. In addition there will also be effluent from blowdown of the auxiliary boilers and the PWTF. Each of these are described in more detail in the following sections.

In addition the contents of a back-up water storage tank (described in Section 4.3) are discharged to the Seal Pit in each refuelling outage period (1,000 m^3 purified water).

The UK ABWR is designed so that discharges of liquid effluent from process activities (and chemicals within this effluent) to the environment are limited, both in volume and in relation to the chemicals present. This is achieved primarily through the strategy to re-use water within the UK ABWR, and therefore to treat the effluent sufficiently to allow for this re-use. All of the process effluents, and the cooling water, are discharged to a single Seal Pit from which they flow to the cooling water outfall for discharge to the sea. Therefore the process effluents that are not retained for re-use within the UK ABWR are subject to significant dilution by the cooling water prior to discharge to the sea.

5.3.1 Cooling Water Systems

The cooling water systems for the UK ABWR are described in Section 4.4.2; three of these, the CW, RSW and TSW are once-through systems and discharge seawater back to the sea. The TCW and RCW systems are both closed loop systems [Ref-14], and their only interaction with the TSW and RSW systems is the transfer of heat across the relevant heat exchangers. No other materials or contaminants are transferred between the cooling water and service water systems.

- CW - discharge of seawater from the CW system is 184,800 m^3/h under normal operation. Under outage conditions the discharge rate will be between 0 and 184,800 m^3/h. The CW system is also designed to remove scale in each cooling tube of the condenser through physical processes (ball cleaning and backwashing during operation of the plant). These washings are discharged to sea within the CW system discharge. Chemical dosing to manage bio-fouling within the CW discharge system will be addressed at site-specific stage as it requires consideration of the characteristics of the receiving environment for the discharge (Section 5.3.1.2). No other chemical dosing of the CW system has been identified at this stage [Ref-13].

- TSW - under normal operation the discharge rate from the TSW system is approximately 7,400 m^3/h. Under outage conditions the discharge rate will be between 3,700 and 7,400 m^3/h approximately, and under abnormal/emergency conditions the discharge rate will be approximately 11,100 m^3/h.
- RSW - under normal operation the discharge rate from the RSW system is approx. 10,800 m^3/h. In shutdown operation and under abnormal/emergency conditions the discharge rate will be approx. 16,200 m^3/h, decreasing to approx. 5,400 m^3/h in accordance with the decrease in core heat load during the outage period.

The TSW and RSW systems are dosed with ferrous ions in order to deposit an iron oxide layer on the tubing internals. Details of the ferrous ion dosing strategy are presented in Section 4.4.2.1.

The discharges from these three once-through systems are mixed in the Seal Pit before discharge to the sea.

5.3.1.1 Potential Contaminants Present (Cooling Water Systems)

The function of the three once-through systems is purely a cooling one, with seawater taken in, passed through a heat exchanger and discharged. None of systems (CW, TSW and RSW) receive drainage from other areas within the ABWR facility. Consequently, the cooling water systems should not have any radioactive or non-radioactive contaminants present, apart from those added specifically (see the chemical dosing strategy (Section 5.3.1.2) and the bullet points below).

The cooling function of all three systems means that the seawater discharged from these systems will be warmer than the intake, and consequently warmer than the water in the receiving environment around the discharge point.

- CW system - Chemical (biocide) dosing to manage bio-fouling within the CW discharge system will be addressed at site specific stage. Other than this, no chemicals are added to the CW system. Scale washings from the condenser cooling tubes may be present. The thermal uplift of the seawater discharged is expected to be 12°C (at point of discharge). Discharge should therefore comprise seawater (at higher temperature than receiving water) and scale washings. The discharge stream is sampled at a Seal Pit before final discharge to confirm that water quality meets the criteria for release (Table 5.3-1).
- TSW system - ferrous ions and/or biocide is added to this system (depending on the type of heat exchanger used (see Section 4.4.2). No other chemicals are added. The thermal uplift of the seawater discharged is expected to be 5.1°C (at point of discharge). The discharge stream is sampled at the Seal Pit before final discharge to confirm that water quality meets the criteria for release (Table 5.3-1).
- RSW system - ferrous ions and/or biocide is added to this system (depending on the type of heat exchanger used (see Section 4.4.2). No other chemicals are added. The thermal uplift of the seawater discharged is expected to be 5.4°C (at point of discharge). The discharge stream is sampled at the Seal Pit before final discharge to confirm that water quality meets the criteria for release (Table 5.3-1).

5.3.1.2 Biocide Dosing

Biocide dosing is required to manage the development of biofilm and biological fouling (bio-fouling) of the cooling water system. Bio-fouling is the attachment and subsequent growth of organisms on manmade structures exposed to seawater. Bio-fouling of pipework and heat exchanger will reduce the carrying capacity of the pipes and the movement of cooling water through them, leading to losses in cooling efficiency, mechanical damage, and impacts to the integrity of the cooling circuits [Ref-18]. Management strategies for bio-fouling typically comprise a combination of physical screening, physical cleaning and chemical dosing.

Biocide dosing will be undertaken into the Circulating Water (CW), Reactor Building Service Water (RSW) and the Turbine Building Service Water (TSW) systems to prevent bio-fouling. The management system used for the biocide dosing depends on the basis of the design of the discharge system and the biological community in the sea around the outfall. The design of the discharge pipes and the outfall will be undertaken at the site-specific stage as these aspects will be determined (in part) by site-specific issues. The biological community around the outfall is also a site-specific issue and will influence the design of the discharge and outfall. Therefore, the selection of the management strategy, including chemical dosing, for the UK ABWR will be made at the site-specific stage.

Sodium hypochlorite, a chlorine-based disinfectant, is a biocide chemical that is compatible with the cooling water system of the UK ABWR and is suitable for large scale surface purification and water disinfection. Sodium hypochlorite is therefore a candidate biocide for the management of bio-fouling in the UK ABWR at site specific stage. Chlorine-based disinfectants are the standard biocides of use in all power stations using once-through seawater cooling [Ref-26]. The assessment of the impact of a biocide from the generic site is made on the basis of sodium hypochlorite.

5.3.2 Drainage Networks

The drainage networks within the UK ABWR facility are categorised according to:

- Where the waste water is generated (from controlled or non-controlled areas).
- The presence (and level) of radioactivity, seawater, detergents and chemical impurities.

The flow diagram in Figure 5.3-1 presents the categorisation methodology applied by Hitachi-GE for the aqueous waste drainage streams.

The drainage from the ABWR facility consists of the following effluent streams:

- Service Water Storm Drain (SWSD) (Section 5.3.2.1).
- Non-radioactive Storm Drain (NSD) (Section 5.3.2.2).
- Controlled Area Drain (CAD) (Section 5.3.3.1).
- High Chemical impurities Waste (HCW) (Section 5.3.3.2).
- Laundry Drain (LD), which includes the Hot Shower Drain (HSD) (Section 5.3.3.4).
- Low Chemical impurities Waste (LCW) - component liquid waste drain and the floor liquid drain (Section 5.3.3.3).
- Boiler blowdown (Section 5.3.4).
- Effluent from the PWTF (Section 5.3.5).
- Site drainage (rainwater) (Section 5.3.6).

The NSD and SWSD capture liquid effluent from non-controlled areas of the site, and the associated waste streams should therefore have zero radioactive contamination.

The CAD, HCW, LD and LCW drainage streams arise from controlled areas of the site and may therefore have radioactive contaminants present. These drainage streams make up the ABWR's LWMS [Ref-19]. Further information on these is provided in Section 5.3.3.

Figure 5.3-2 provides an overview of management and ultimate disposal routes for the SWSD, NSD and LWMS's effluent streams. Further detail on the LWMS is presented in Figure 5.3-3.

5.3.2.1 Service Water Storm Drain (SWSD)

The SWSD receives service water (seawater) discharged from the RCW and TCW Heat Exchangers, RSW and TSW pumps and piping during maintenance, or in the event of unintentional leakage from the RSW or

TSW systems. The RSW and TSW pumps circulate the seawater in the RSW and TSW cooling systems through the RCW and TCW heat exchangers (Section 5.3.1). The pipes and valves that comprise the SWSD are constructed of a material(s) resistant to corrosion by seawater [Ref-20].

The SWSD drains to the SWSD sump and is then pumped directly by the SWSD pump to the sea via the Seal Pit. The discharge is monitored by grab sampling to ensure that discharge criteria are met (Table 5.3-1). The discharge rate from the SWSD drain is determined by the capacity of the SWSD pump. Discharges into the SWSD drain are not constant. The normal discharge rate is estimated (on this basis) as 24 m^3/day, with a maximum of 240 m^3/day.

Liquid effluent cannot be held within the SWSD (or NSD) drainage lines. Effluent collected by these drainage routes drains to the relevant sumps. These only have a small capacity and when sufficient volume of effluent is present, the discharge pumps are activated and the effluent in the sumps is discharged to the Seal Pit.

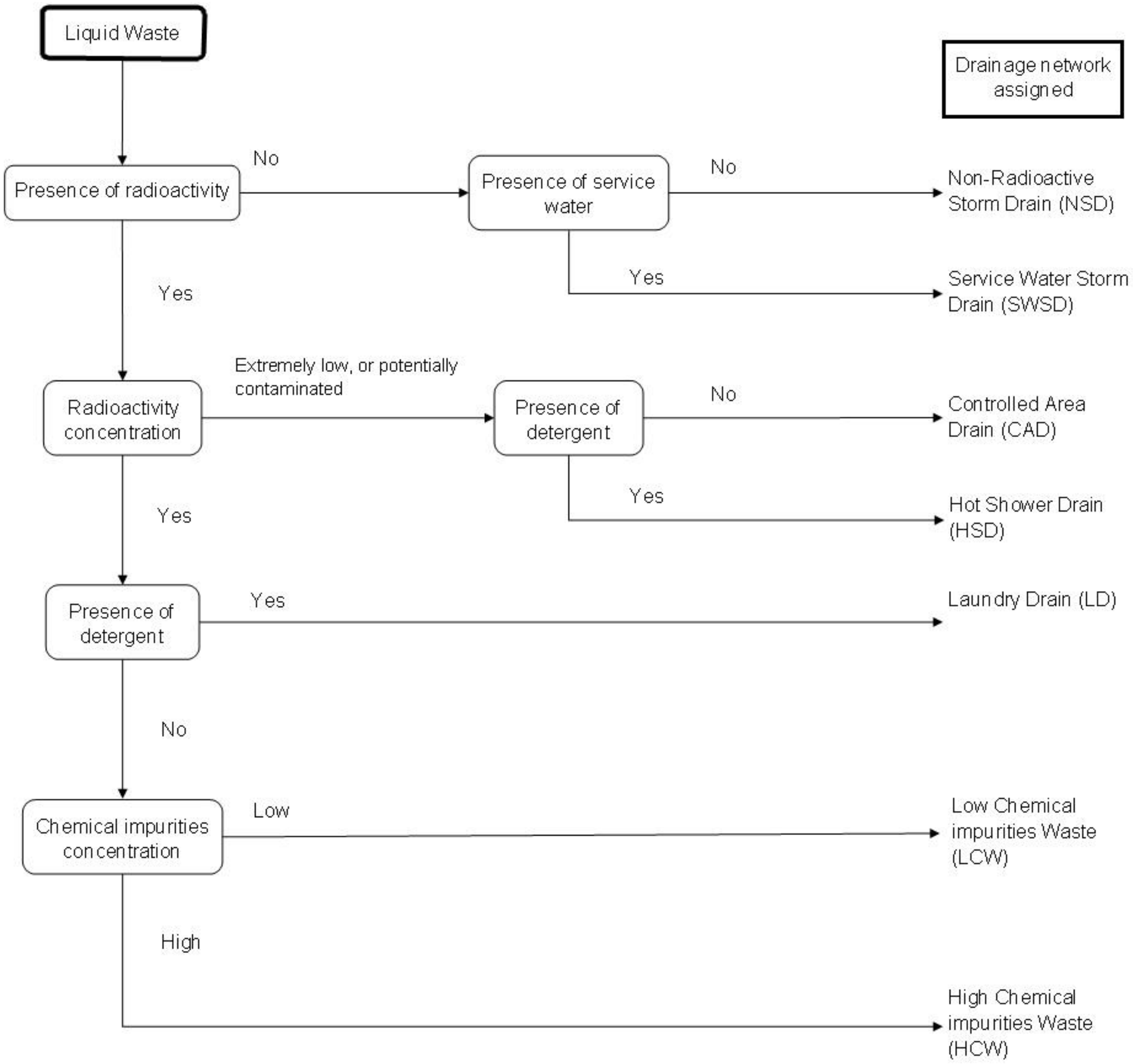

Figure 5.3-1: Classification of the Aqueous Waste Streams

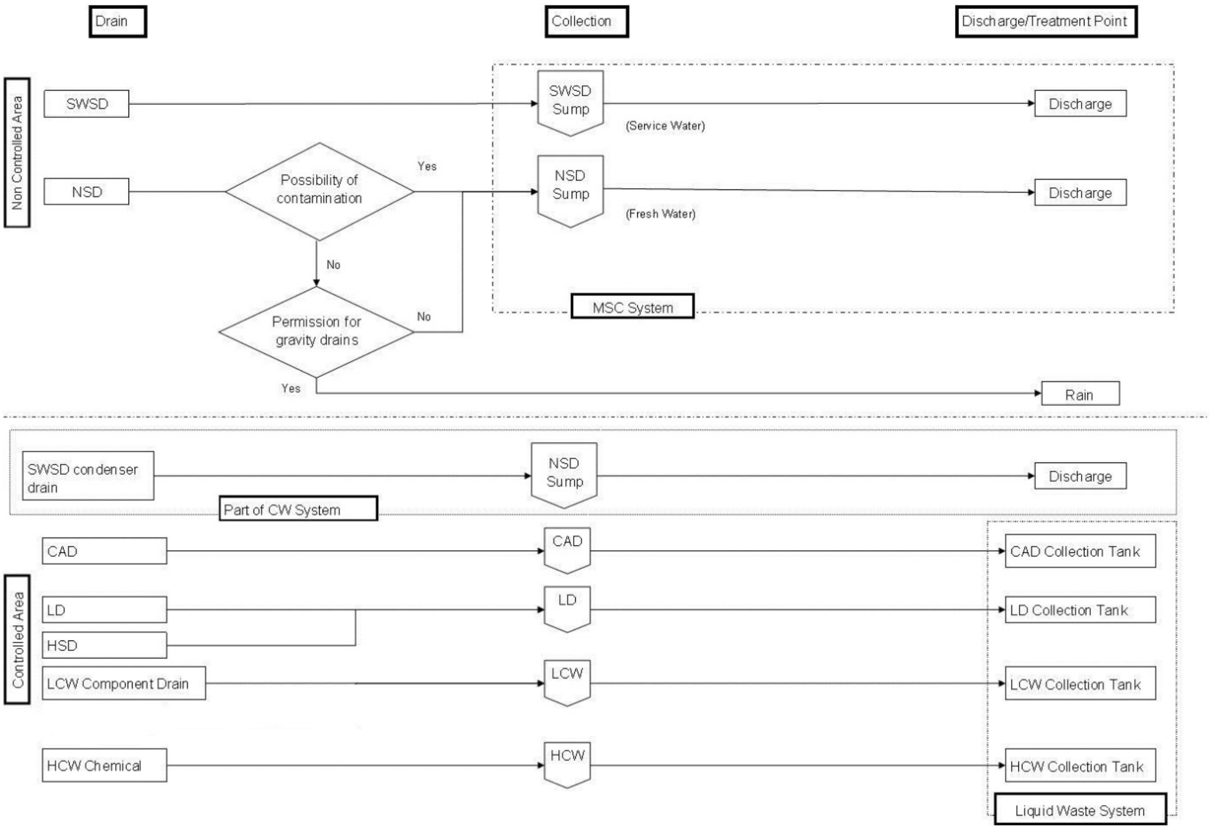

Figure 5.3-2: Overview of Liquid Waste Treatment Flows

Table 5.3-1: Discharge Criteria for Liquid Waste to the Environment (criteria apply to liquid discharges from SWSD, NSD, CAD and LD)

Item	**Criteria**	
pH	5.8 - 8.6	
Chemical oxygen demand (COD)	<30 mg/l	Daily maximum
	<20 mg/l	Daily average
Suspended solids	<20 mg/l	Daily maximum
	<15 mg/l	Daily average
Concentration of normal-hexane extract	<3 mg/l	Daily maximum

Note: These are the criteria for Japanese ABWR and are presented here to demonstrate the level of discharge control in place for the ABWR NPP.

5.3.2.1.1 Potential Contaminants Present (SWSD)

Potential contaminants within the SWSD system should be minimal. As the system drains from non-controlled areas of the site, radioactive contaminants should be negligible.

5.3.2.2 Non-radioactive Storm Drain (NSD)

The NSD receives arisings from non-radioactive drains in non-controlled areas. The NSD drainage stream differs from the SWSD stream described above in that the liquid is purified water rather than seawater (service water) (Figure 5.3-1).

The NSD receives liquid waste from the following systems:

- RCW.
- TCW.
- Purified water system - supplies the cooling water expansion tank of the diesel cooling water system.
- Station Service Air System (SA).
- Instrument Air System (IA).
- Heating Ventilating and Air Conditioning System (HVAC).
- HVAC Normal Cooling Water System (HNCW) - used as a cooling resource within the HVAC system.
- HVAC Emergency Cooling Water System (HECW) - used as a cooling resource within the HVAC system.

The NSD system drains to the NSD sump and is then pumped directly to the Seal Pit by the NSD pump. A radiation monitor in the discharge line monitors for the presence of radioactive material in the discharge. Monitoring is also undertaken for the presence of corrosion inhibitors (rust preventing agents), such as nitrite, in the waste stream.

Corrosion inhibitors may enter the NSD system following drain down from the TCW, RCW, HNCW or HECW systems for maintenance purposes. The TCW, RCW, HNCW and HECW systems are located within controlled and non-controlled areas in the UK ABWR. The NSD drain only receives drain down from these systems where they are located within non-controlled areas. Drain down from these systems where they are located within controlled areas occurs directly to the CAD system (via the CAD sump).

The quantities of liquid effluent released from the main equipment in each of the TCW, RCW, HNCW and HECW systems during maintenance are estimated as follows:

- RCW system – composed of three closed loops corresponding to Division A, Division B and Division C of the Emergency Core Cooling System (ECCS) [Ref-12]. Each division (A, B and C) contains two RCW heat exchangers and one Residual Heat Removal System (RHR) heat exchanger. Divisions A and B each have two Reactor Water Clean-up System (CUW) heat exchangers and one Fuel Pool Cooling and Clean-up System (FPC) heat exchanger. Drain down of the RCW system would result in 24.9 m^3 from two RCW heat exchangers, 6.25 m^3 from one RHR heat exchanger, 2.43 m^3 from two CUW heat exchanger and 0.98 m^3 from one FPC heat exchanger. A maintenance period is not available for the RCW system. It should be noted that the entire contents of the RCW system would not be drained down at any one time. If it is necessary to drain part of the system (e.g. for maintenance), the section of the system that needs draining would be isolated by valves prior to drain down.
- TCW system – 30 m^3 from the TCW Heat Exchanger. The TCW system has three TCW Heat Exchangers. Discharge from more than one TCW Heat Exchanger at the same time is not expected. A maintenance period is not available for the TCW Heat Exchangers.
- HNCW system - 1.3 m^3 from the HNCW Chiller. The HNCW system has a total of ten HNCW Chillers. Drain down for maintenance is conducted once every two years. The maintenance regime means that drain down (and therefore discharge) from more than one chiller is not expected to occur at the same time.

- HECW system - 0.3 m^3 from the HECW Chiller. The HECW system has four HECW Chillers per division. Drain down for maintenance is conducted once every two years. The maintenance regime means that drain down from more than one chiller is not expected to occur at the same time.

The discharge rate from the NSD drain is determined by the capacity of the NSD pump. Discharges into the NSD drain are not constant. Normal discharge rate is estimated (on this basis) as 24 m^3/day, with a maximum of 240 m^3/day.

If the aqueous waste that is collected in the NSD sumps exceeds the discharge limits or contains radioactive materials, then the waste will be treated appropriately according to the property of drains, for example diluted by water or transferred to the radioactive waste facility through a temporary connection.

5.3.2.2.1 Potential Contaminants Present (NSD)

The NSD system should have no radioactive contaminants present, as a consequence of it draining from non-radioactive drains in non-controlled areas. Monitoring arrangements for the NSD system will be determined at the site-specific stage.

Non-radioactive contaminants present in the NSD discharge stream are a corrosion inhibitor (nitrite (NO_2^-)). This is present following dosing at 200-300 ppm into the auxiliary equipment cooling systems (TCW, RCW, HNCW and HECW) to prevent rusting within the piping and heat exchanger tubes.

5.3.3 Drainage Networks - Liquid Waste Management System

As introduced in Section 5.3.2, the LWMS system comprises the CAD, HCW, LCW and LD drainage systems, and has the following overarching strategic functions [Ref-21]:

- To contain any water leaks and any water drained from the closed loop systems of the Primary Circuit and/or the Fuel Pool [Ref-19].
- To control, collect, process, handle, store and dispose of liquid wastes generated as the result of normal operations.
- To enable the re-use (recycling) of treated liquids where possible, so that liquid discharges (including radioactive contaminants) are minimised as far as practical.
- To have sufficient capacity so as to be able to deal adequately with anticipated cases in which the maximum amounts of waste liquids are generated.
- To have systems in place to prevent leakage of liquid radioactive substances, and uncontrolled discharge outside of the ABWR site.
- To collect all potentially radioactive liquid wastes in dedicated systems (sumps or drain tanks) [Ref-22].

An overview and ultimate disposal routes of the four effluent streams within the LWMS is presented in Figure 5.3-2. Further detail on the LWMS is presented in Figure 5.3-3.

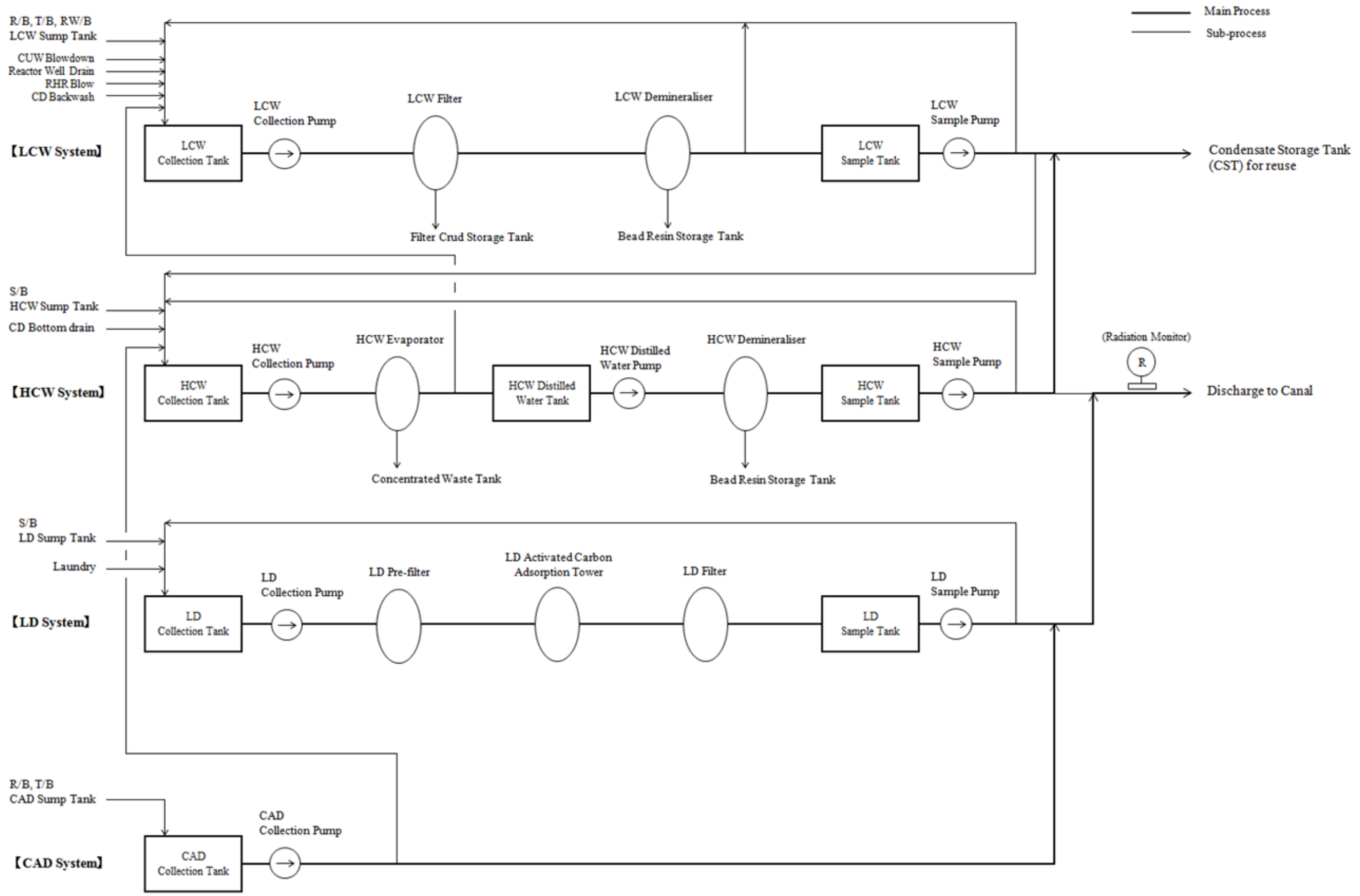

Figure 5.3-3: Outline of Liquid Waste Management System (LWMS)

As shown in Figure 5.3-3 there are linkages within and between the LCW, HCW, LD and CAD systems (which collectively make up the LWMS).

Linkages between the systems allow for the transfer of effluent according to the level of contamination present. This improves the efficiency and efficacy of the LWMS and prevents the overloading of a system should it receive waste that it is not capable of treating effectively, for example during an unplanned release.

Linkages within each system allow for the re-circulation of effluent through a system multiple times to enable the required level of treatment to be achieved. The linkages between and within the systems are shown on Figure 5.3-3, and are discussed in Table 5.3-2, below. The criteria for the effluent linkage transfers are also presented in Table 5.3-2.

Table 5.3-2: Transfer Linkages for Effluent between and within LWMS

Transfer from	Transfer to	Criteria	Threshold (to trigger transfer)
Downstream of LCW sample pump	LCW collection tank	Conductivity	>100 µS/m
		pH	<5.6 or >8.0
		Cl^-	>20 ppb
		SO_4^{2-}	>20 ppb
		TOC	>400 ppb
Downstream of HCW sample pump	HCW collection tank	Radioactivity (tritium)	>3.7 x 10^{12} Bq/y
		Radioactivity (except tritium)	>3.7 x 10^{10} Bq/y
		pH	<5.6 or >8.6
		COD (maximum/day)	>30 mg/l
		COD (average/day)	>20 mg/l
		Suspended solids (maximum/day)	>20 mg/l
		Suspended solids (average/day)	>15 mg/l
		Normal hexane extracts (maximum/day)	>3 mg/l
Downstream of LD sample pump	LD collection tank	Radioactivity (tritium)	>3.7 x 10^{12} Bq/y
		Radioactivity (except tritium)	>3.7 x 10^{10} Bq/y
		pH	<5.6 or >8.6
		COD (maximum/day)	>30 mg/l
		COD (average/day)	>20 mg/l
		Suspended solids (maximum/day)	>20 mg/l
		Suspended solids (average/day)	>15 mg/l

Transfer from	Transfer to	Criteria	Threshold (to trigger transfer)
		Normal hexane extracts (maximum/day)	>3 mg/l
Downstream of CAD collection pump	HCW collection tank	Radioactivity (tritium)	>3.7 x 10^{12} Bq/y
		Radioactivity (except tritium)	>3.7 x 10^{10} Bq/y
		pH	<5.6 or >8.6
		COD (maximum/day)	>30 mg/l
		COD (average/day)	>20 mg/l
		Suspended solids (maximum/day)	>20 mg/l
		Suspended solids (average/day)	>15 mg/l
		Normal hexane extracts (maximum/day)	>3 mg/l
Downstream of HCW sample pump	CST	Conductivity	<100 µS/m
		pH	5.6 - 8.0
		Cl^-	<20 ppb
		SO_4^{2-}	<20 ppb
		TOC	<400 ppb

Note - Discharge criteria presented in the table are actual environmental discharge criteria of Japanese ABWR. Discharge criteria for UK ABWR will be set at the site-specific permitting stage.

5.3.3.1 Controlled Area Drain (CAD)

The CAD system collects drainage and sampling water from non-radioactive equipment systems in the controlled areas of the Reactor Building (R/B) and Turbine Building (T/B) [Ref-23]. The effluent collected in the CAD system is potentially contaminated but is expected to be essentially free from radiological contamination [Ref-23]. The CAD system receives liquid arisings from the:

- CAD sump tank in the R/B.
- CAD sump tank in the T/B.
- Drain down (for maintenance purposes) from the TCW, RCW, HNCW and HECW systems that within controlled areas within the UK ABWR.

The liquid waste streams drain to two CAD collection tanks, and are then pumped to the discharge point to sea. Liquid is sampled from the CAD collection tanks and analysed for chemical and radioactive contaminants. If the liquid meets the required criteria (Table 5.3-1) it is discharged to the sea. If the discharge criteria are not met then the effluent is transferred to the HCW collection tank for treatment within the HCW system (as shown in Figure 5.3-3).

There is no mechanism to transfer effluent from the CAD system into the CST, as is the case for the HCW and LCW systems. Therefore, the liquid effluent discharged from the CAD system is released to the environment, via the Seal Pit. Discharge from the CAD drainage line can be stopped by collecting effluent in the CAD collection tank which is installed on the discharge line (see Figure 5.3-3 for more details).

Information on the quantity of liquid effluent discharged from the CAD system is presented in the Generic Pre-Construction Safety Report [Ref-19]. Typically this is expected to be approximately 3 m^3/day.

5.3.3.1.1 Potential Contaminants Present (CAD)

Because of the equipment it services, the CAD system should be essentially free of radioactive contaminants [Ref-22]. Non-radioactive contaminants may include sodium nitrite corrosion inhibitor, which is discharged directly to the CAD system from drain down (generated during maintenance of the TCW, RCW, HNCW or HECW systems that are within controlled areas within the UK ABWR).

Effluent from the CAD system can be diverted to the HCW collection tank if any unacceptable chemical contamination (or significant radiological contamination) is detected, which will minimise the levels of contaminants discharged to sea from this system.

5.3.3.2 High Chemical impurities Waste (HCW)

The HCW system (located in the Radioactive Waste Building (Rw/B) is a radioactive treatment system, designed for the treatment of liquids containing radioactive contaminants. However, the treatment technologies employed are not specific for the removal of radionuclides and are also effective in managing any non-radioactive contaminants present.

The main feeds into the HCW system are the waste water from the chemical analysis laboratory (hot lab) drains in the Service Building (S/B) and the condensate demineraliser drains. These effluent feeds either contain radioactive contaminants, or have the potential for radioactive contaminants to be present. Chemicals present in the waste water from the chemical analysis include small quantities of phosphoric acid and hydrochloric acid, sodium bicarbonate solution and potassium permanganate solution, silver nitrate, as well as cation and anion eluents from chromatography analyses. For full information of chemicals from the chemical analysis is shown in Table 5.3-3. It should be noted that chemicals shown in the table is based on J-ABWR practice and used chemicals could be reviewed by future operator at site specific stage. The volumes of each chemical discharged into the HCW system are typically <100 mls, with a maximum volume of 2 litres for a minority of the chemicals. Acidic solutions are neutralised in the HCW collection tank with sodium hydroxide[1], prior to treatment through the HCW system. A further feed into the HCW system is effluent from the CAD system that arises from the drain down of closed loop cooling systems (such as TCW and RCW) located within controlled areas of the UK ABWR. This effluent does not contain radioactive contaminants but does contain sodium nitrite (a corrosion inhibitor). This effluent will only be generated during maintenance activities undertaken in outage periods.

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[1] Sodium hydroxide used will be free of mercury and cadmium.

Table 5.3-3: Chemicals from the Laboratory Samples into the HCW System

Name	Specification	Usage/time	Usage/year	Purpose (Sampling)
Phthalate Standard Solution	pH 4.01 (at 25℃), 500 ml	20 ml	1,000 ml	pH standard solution
Phosphate Standard Equimolar Solution	pH 4.01 (at 25℃), 500 ml	20 ml	1,000 ml	pH standard solution
Tetraborate Standard Solution	pH 4.01 (at 25℃), 500 ml	20 ml	1,000 ml	pH standard solution
Silicon Standard Solution	1,000 ppm, 100 ml	1 ml	200 ml	Silica
Sulphuric acid	(1+5), 500 ml	1 ml	500 ml	Silica
Ammonium molybdate	40 g/ 400 ml	2 ml	1,000 ml	Silica
Oxalic acid dihydrate	20 g/200 ml	1.5 ml	750 ml	Silica
Ascorbic acid	20 g/200 ml	1 ml	500 ml	Silica
Multi cation Standard Solution	50 ml (Li: 0.5 ppm, Na: 2 ppm, NH_4: 2 ppm, K:5 ppm, Ca: 5 ppm, Mg: 5 ppm)	1 ml	100 ml	Ion Chromatography
Multi anion Standard Solution	50 ml (F: 5 ppm, Cl: 10 ppm, NO_2:15 ppm, Br:10 ppm, NO_3:30 ppm, PO_4: 30 ppm, SO_4: 40 ppm)	1 ml	100 ml	Ion Chromatography

Cr Standard Solution	1,000 ppm, 100 ml	1 ml	200 ml	Ion Chromatography
Cation eluent	(99% Methane sulfonic acid 1.3 ml)/l	2 l	2 l	Ion Chromatography
Anion eluent	(Na_2CO_3: 28.62g + $NaHCO_3$: 2.52g)/l	2 l	4 l	Ion Chromatography
Boron Standard Solution	100 ml	1 ml	200 ml	Ion Chromatography
Boron eluent	Sodium octane sulfonate 1 mmol/l	2 l	2 l	Ion Chromatography
Potassium hydrogen phthalate	1,000 ppm/100 ml	1 ml	200 ml	TOC
Phosphoric acid	62.5 ml/250 ml	250 ml	250 ml	TOC
Hydrochloric acid	1 N, 500 ml	20 ml	500 ml	TOC
Sulfuric acid	(1+5), 500 ml	5 ml	2,075 ml	Nitrite ion
Sodium Oxalate	N/10, 500 ml	10 ml	4,150 ml	Nitrite ion
Potassium permanganate	N/10, 500 ml	20 ml	8,300 ml	Nitrite ion
Nitric acid	(1+2), 500 ml	5 ml	2,075 ml	Chloride ion
Silver nitrate	2 g/ 200 ml (1 w/v%)	1 ml	415 ml	Chloride ion

Effluent is treated in the HCW system (and LCW system) to a high standard such that it is suitable for re-use within the UK ABWR [Ref-78].

The liquid waste streams discharged into the HCW system are collected in two HCW collection tanks. Effluent is then pumped from these through the treatment process (see Section 5.4) to the HCW sample tank. During the treatment process some of the treated effluent is re-circulated back to HCW collection tanks. Radioactive materials removed during treatment are collected and contained in the form of wet sludges and used ion exchange resins. These wet-solid wastes are stored in the concentrated waste tank and spent resin storage tank, before transfer to the solid radioactive waste treatment facility for processing into a passively safe state [Ref-22]. Treated effluent is transferred to the HCW sample tank. The linkage between the HCW and LCW systems (downstream of the HCW evaporator) allows the LCW demineraliser to be used if the HCW demineraliser is not available.

The water quality of the treated effluent is analysed in the HCW sample tank. If the treated effluent meets the acceptance criteria of the CST (Table 5.3-4), it is transferred to the CST, mainly for re-use as reactor primary circuit or fuel pool make-up water [Ref-23]. Effluent sent to the CST for re-use will meet the acceptance criteria of the CST. If the effluent does not meet the acceptance criteria it is re-routed to the HCW collection tank for re-treatment through the HCW system. This process can be undertaken multiple times if required, until the effluent meets the acceptance criteria for the CST.

If the water balance within the UK ABWR is such that there is not the physical capacity in the CST to receive treated effluent[2] from the HCW system, then the treated effluent may be held temporarily in the HCW sample tank, rather than being transferred to the CST. If temporary storage is not possible in the HCW sample tank, then the treated effluent is discharged from the HCW sample tank to the Seal Pit (and from there to the sea). Discharge of treated effluent from the HCW system to the environment may therefore occur, but only in the event of water balance constraints within the UK ABWR. Effluent discharged from the HCW sample tank will have been through the HCW treatment system and will meet the acceptance criteria of the CST (Table 5.3-4). Any discharge from the HCW system to the Seal Pit will therefore be CST quality water. The discharge of treated effluent from the HCW sample tank occurs as a batch discharge only.

There is no discharge from the CST to the HCW system or the Seal Pit.

Table 5.3-4: Acceptance Criteria for the Condensate Storage Tank (CST)

Criteria	Acceptance threshold
Conductivity	<100 μS/m
pH	5.6 – 8.0
Cl^-	<20 ppb
SO_4^{2-}	<20 ppb
TOC	<400 ppb

These criteria values for the CST are defined as provisional values at GDA stage. The detailed values will be determined at site license stage.

[2] Defined as when the volume of liquids within the cooling circuit and pools reaches its maximum working capacity [Ref-78].

5.3.3.2.1 Potential Contaminants Present (HCW)

The function of the HCW system as the recipient for the more contaminated liquid effluents generated within the UK ABWR, means that the HCW system will contain various non-radioactive and radioactive contaminants. The HCW system is designed so that the contaminants present are removed from the effluent stream into spent resins and the concentrated waste tank during the effluent treatment process. Sodium hydroxide[3] and sodium dihydrogen phosphate (corrosion inhibitor) are added to the HCW system. These chemicals are concentrated in the HCW evaporator and removed to the Concentrated Waste (CONW) system as concentrated liquid waste. Consequently they are not discharged to the environment. The discharge limits are detailed in Table 5.3-1.

Treatment within the HCW system is achieved through a combination of an evaporator and a demineraliser. These techniques provide a non-specific (catch all) treatment system designed to remove the types of contaminants likely to be present in the HCW system. The evaporator is designed to enable the removal of the insoluble contaminants present (into a solid waste stream), with the volatile contaminants not captured by the evaporator subsequently removed by the demineraliser. The combination of these treatment technologies is effective in removing both inorganic and organic contaminants present in the effluents routed to the HCW system. With regard to the discharges from the chemical analysis laboratory, the combination of the evaporator and demineraliser treatments will be sufficient to remove the chemicals likely to be present. The demineraliser treatment stage in the HCW system will be effective in removing the sodium nitrite present.

Effluents are routed to the HCW system on the basis of them containing radioactive contaminants, or having the potential for radioactive contaminants to be present. The exception is effluent from the CAD system that arises from the drain down of closed loop cooling systems (such as TCW and RCW) located within controlled areas of the UK ABWR. Effluent within the CAD system should be free of radioactivity but does come from controlled areas within the UK ABWR. This effluent does not contain radioactive contaminants but does contain sodium nitrite (a corrosion inhibitor). This effluent will only be generated during maintenance activities undertaken in outage periods. The demineraliser treatment stage in the HCW system will be effective in removing the sodium nitrite present.

The discharge of treated effluent from the HCW sample tank occurs as a batch discharge only. Information from Japanese ABWR reports an average of 2.5 discharges a year, totalling approximately 288 m^3/year [Ref-24], and therefore approximately 115 m^3 per batch discharge.

The treated state (CST quality) of the discharge from the HCW sample tank means that potential impacts of this to the marine environment will be very low. There are no significant contamintants present, and dilution of the effluent in the cooling water is expected to result in any potential impact being negligible.

5.3.3.3 Low Chemical impurities Waste (LCW)

The LCW system is located within the RW/B building and is designed to treat relatively large volumes of radioactively or potentially radioactivity contaminated waste water [Ref-22]. The LCW system receives liquid arisings from the:

- LCW sump tank in the R/B, T/B and RW/B. This collects waste water spillages in each separate area of the R/B, T/B and RW/B.
- CUW blowdown.
- Reactor well drain.

[3] It is proposed that the sodium hydroxide used will be free of mercury and cadmium.

- RHR blow.
- HCW system downstream of the HCW evaporator.

The LCW liquid effluent route is differentiated from the HCW discharge stream by a lower level of radioactive contamination and lower levels of chemical impurities.

There is sufficient capacity within the LCW sumps (and associated pumps) to handle any liquid spillages within the R/B, T/B and RW/B that may occur during normal operations, start-up, shut-down and outages [Ref-23].

The liquid waste streams discharged into the LCW system are collected in the LCW collection tank. Effluent is then pumped from these through the treatment process (see Section 5.4) to two LCW sample tanks.

During the treatment process some effluent is removed to the sludge and spent resin storage tanks. Following treatment, effluent may also be re-circulated back to the LCW collection tank for retreatment through the system.

The treated effluent is analysed in the LCW sample tanks. All treated effluent in the LCW sample tank is reused within the ABWR facility. If the effluent is suitable for re-use it is transferred to the CST. If it is not suitable for re-use it is re-circulated back to the LCW collection tank (as shown in Figure 5.3-3). There is no direct discharge to sea from the LCW system, or from the CST.

5.3.3.3.1 Potential Contaminants Present (LCW)

As with the HCW system, the purpose of the LCW system as a recipient system for contaminated liquid effluents generated within the UK ABWR means that the LCW system will contain various non-radioactive and radioactive contaminants. However, the LCW system is designed so that the contaminants present are removed from the effluent stream into wet sludges and spent resins during the effluent treatment process (for disposal as solid waste). No chemicals are added to the LCW system for operation or maintenance purposes.

There is no discharge from the LCW system to the sea, with the liquid effluent from the end of the LCW system either discharged to the CST or re-circulated back to the LCW collection tank. There is no discharge directly from the CST to the environment.

5.3.3.4 Laundry Drain (LD)

The LD receives liquid effluent from the laundry, personal showers (via the HSD) and hand washing facilities [Ref-23] within the S/B; the water source for all of these facilities is towns water.

The quantity of liquid discharged from the LD system is dependent on the number of people using the controlled area. The discharge during normal plant operation assumes 200 people entering the controlled area per day. The maximum discharge is assessed to occur during periodic plant inspection as a consequence of 1,800 people entering the controlled area per day [Ref-19]. Using these figures, and an operating regime of 11 months normal operation and one month outage for periodic inspection, the annual discharge from the LD system is approximately 2,240m^3/year. Detergent use in this period is approximately 750 litres.

A decision on the detergent to be used will be made at site specific stage by the site operator. However, a detergent such as Manoxol OT, a commercially available anionic surfactant based detergent, would be suitable for example. The assessment of impact at generic stage is made on the basis of Manoxol OT as the detergent used.

These liquid waste streams drain via the LD sump tanks in the S/B buildings to two LD collection tanks. The effluent is then pumped through the treatment process (see Section 5.4) to two LD sample tanks where the water quality is analysed for chemical and radioactive contaminants. If the effluent meets the discharge criteria it is then discharged to the sea (Table 5.3-1).

The discharge from the personal showers should have negligible levels of radioactive contaminants, whereas the laundry discharge may contain some radioactive contaminants [Ref-18][Ref-22].

The presence of detergent in the LD liquid effluent stream means that it is not suitable for recycling and re-use within the main ABWR plant. The potential presence of radioactive contaminants is likely to preclude re-use within ancillary systems (toilets for example).

If on analysis in the LD sample tank the effluent does not meet the criteria for discharge to sea (Table 5.3-1) then the liquid is transferred back to the LD collection tank (as shown in Figure 5.3-3) for re-circulation through the LD system. Re-circulation (and therefore re-treatment) can be repeated multiple times if required. There is no mechanism to transfer effluent from the LD system to the CST.

5.3.3.4.1 Potential Contaminants Present (LD)

No chemicals are added to the LD system during operation or maintenance. The only potential contaminants present in the LD discharge system are detergents, suspended solids and organic materials, and possibly low levels of radioactive material.

Treatment of the effluent captured by the LD system will remove some of the contaminants to filters and activated charcoal units. The discharge limits are detailed in Table 5.3-1. If the discharge does not meet the criteria set then it is not discharged to sea and is re-routed back to the LD collection tank for re-treatment through the process.

5.3.4 Boiler Blowdown

The addition of chemicals is required to maintain the quality of the water within the boiler system. The use of purified water as the feedwater for the boiler system reduces the requirement for chemical dosing compared with systems using townswater for example as feedwater. For the purposes of GDA, the chemicals used are phosphate and hydrazine (N_2H_4)[4]. These provide a pH control and deoxidiser function respectively. Continuous blowdown of the boiler water is required to control boiler water parameters within prescribed limits to minimise scale, corrosion, carryover, and to remove suspended solids. The addition of phosphate and hydrazine into the boiler water means that quantities of each may be present in the boiler blowdown liquid effluent. Small quantities of corrosion products from the boiler system are also likely to be present in the effluent.

Phosphate is present in the blowdown at a concentration of 3 ppm.

The function of hydrazine as a deoxidiser means that the hydrazine should be degraded in the boiler water system in the presence of oxygen to form water and nitrogen[5]. The potential for hydrazine to be present in the blowdown will depend on the dosing level of hydrazine into the boiler system, and the level of oxygen in the boiler water (which will determine the level of degradation of the hydrazine. Each boiler operating at full load would require hydrazine dosed to a concentration of 0.2 ppm. Physical measures (such as physical degassing, the bubbling of nitrogen or steam through the boiler feedwater to displace oxygen), would be implemented to reduce the level of dissolved oxygen in the boiler feedwater. Such measures will minimise the amount of hydrazine required.

[4] At site-specific stage the chemicals required will be reviewed, and may be different from those presented at GDA stage.

[5] At high temperatures, hydrazine will undergo decomposition to ammonia and water. The temperatures required for this reaction will not be experienced in the boiler water system. Therefore ammonia will not be produced and will not be present in the blowdown.

The worst case scenario for the hydrazine (in terms of discharges from the boiler system) is that there is no reaction with oxygen to be scavenged from the boiler system, resulting in no degradation of the hydrazine to nitrogen and water. Whilst unrealistic, this scenario is the worst case and would result in hydrazine being present in the blowdown at a concentration of 0.2 ppm. The best case scenario is full degradation of the hydrazine to nitrogen and water, resulting in no hydrazine present in the blowdown.

As discussed, the blowdown of the boiler water occurs as a continuous process. Each boiler operating at full load is estimated to generate 4.7 m^3 of blowdown per day.

The effluent generated is held in a dedicated tank for interim storage prior to disposal in batches to the Seal Pit.

5.3.5 Effluent from the PWTF

The purpose of the PWTF is to produce the high quality water required within the UK ABWR. For the generic design the PWTF will use reverse osmosis and electro-deionisation technologies to convert townswater (potable supply) to the high quality water (de-ionised) required.

The technology used to produce the high quality water required has changed from previous versions of the Other Environmental Regulations (E9) document. In previous versions the technology described was ion-exchange. This technology is suited for sites where the feedwater for the PWTF is of lower quality. Ion-exchange technology is used typically in Japanese ABWR design where the source of the feedwater is a lake or river. In UK ABWR design, the feedwater is townswater which should be higher quality than lake or river water. This allows reverse osmosis and electro-deionisation technology to be used instead.The effluent generated from the PWTF will have the same chemical constituents as townswater, but the chemicals will be at present at double the concentration that they are in the townswater feedwater. No other chemicals are added to the water during the reverse osmosis and electro-deionisation processes, and therefore no other chemicals will be present in the effluent that arises, other than those present in the townswater feedwater. The effluent is generated on a continuous, rather than a batch basis.

The liquid effluent discharged from the PWTF will be discharged to the Seal Pit. If required the effluent may be held in an interim storage tank prior to discharge to the Seal Pit. The volume of effluent generated will be 50% of the volume of townswater feedwater. The chemical characteristics of the effluent will be set by the characteristics of the townswater supply. This will be determined at site specific stage, and further information on the chemicals present is not presented at site specific stage.

5.3.6 Rainwater / Firewater Run-off

Rainwater and firewater runoff will be managed to minimise the potential impacts posed to the environment as a consequence of any contaminants present. The potential impact is determined in part by the site-specific issues, particularly precipitation levels, topography, site layout and surfacing, and the characteristics of the surrounding environment (location of watercourses for example). Therefore the detailed strategy for the management of rainwater and firewater will be addressed at the site-specific stage. At the GDA stage, the approach for managing precipitation is that rainwater run-off from areas within the inner fence drains to the Seal Pit where it is mixed with the discharges from the cooling water systems (CW, TSW and RSW). Water in the Seal Pit is discharged to the sea with regular sampling. Rainwater drainage from areas outside the inner fence (grassed areas of the site, car parks, site roads and walkways) may drain directly to the sea and not go to the Seal Pit first. Drainage of rainwater from areas within the site is expected to be to the Seal Pit.

The drainage system(s) which receive rainwater will have the appropriate measures in place to manage accidental spills of hazardous chemicals and firewater generated in the event of a fire on site. Measures likely to be included are oil interceptors within the drainage systems receiving runoff from roadways (to remove any hydrocarbons that may become entrained in the rainwater), and soakaways or swales to manage runoff from grassed areas. Swales in particular will provide some filtration of the rainwater to removed entrained silt for example, and can also attenuate discharge rates. Measures to manage the larger volumes of liquids that could be released in the event of an accidental spill or a fire (leading to the generation of firewater) will comprise secondary containment around storage areas of hazardous liquids, and supporting tertiary containment systems. These are summarised in more detail in Section 8.7.

5.3.7 Discharge Criteria to Sea

Discharges to sea occur from the SWSD, NSD, HCW, LD, CAD and rainwater drainage routes, as well as from the boiler blowdown and the PWTF.

As detailed in Section 5.3.3, the design of the LWMS system (comprising the HCW, LD and CAD systems) enables liquid effluents to undergo repeated rounds of treatment within the LWMS, with the objective of re-using the treated effluent in the ABWR, rather than discharging all effluent to the environment. This means that contaminants are retained within the UK ABWR (captured in solid waste streams) and releases to the environment minimised. However, as described some discharges to the environment (the sea) occur, specifically from the CAD and LD systems. The criteria for the liquid discharge to the sea are described in Table 5.3-1. These are the criteria for a Japanese ABWR and are presented to demonstrate the level of discharge control in place for the ABWR NPP. Discharge criteria for the UK ABWR will be developed at the site-specific permitting stage to reflect the site-specific component of the potential impacts to the receiving environment. The criteria shown in Table 5.3-1 apply to these systems.

5.4 Effluent Treatment and Assessment of Impacts

Each of the liquid discharge streams described in the previous section are subject to some form of treatment or monitoring to ensure that potential impacts to the environment from the discharges can be identified and mitigated where necessary.

5.4.1 Treatment of Cooling Water Systems (CW, TSW and RSW)

There is no treatment of the discharges from the three cooling water systems (CW, TSW and RSW) prior to their discharge to the sea. However, the discharges from all three systems are monitored to confirm (before release) that discharge criteria are met.

The function and design of the three cooling systems means that the seawater discharged should be free of contamination from the UK ABWR plant, with the exception of biocide and (biocide degradation products). Ferrous ions may be present in the TSW and RSW discharges, if shell and tube type heat exchangers are used in these systems.

5.4.2 Treatment of Drainage Networks (SWSD and NSD)

There is monitoring of the discharge from the SWSD and NSD systems (see Table 5.3-1 for discharge criteria), but no treatment processes are proposed within either system. Whilst the NSD system does not contain any treatment processes, in the event that effluent which does not meet discharge criteria (or radioactive contaminants) is received, appropriate measures will be undertaken (e.g. diluted by water or transfer of the effluent in the NSD system to the radioactive waste facility via temporary facilities).

There is no mechanism to divert discharges from the SWSD system. However, the nature of the SWSD discharge means that the potential for contaminants to be present is extremely low.

5.4.3 Treatment of Drainage Networks (LWMS)

The drainage networks within the LWMS are the CAD, HCW, LCW and LD drainage systems. The purpose of the LWMS is to control, collect, process, handle and store liquid radioactive waste generated as a result of normal operation, including anticipated operational occurrences. The LWMS has the following general design features which will ensure effective containment of the effluent through the treatment process [Ref-23]:

- Tanks, pipes, pumps etc. in the LWMS use appropriate materials, are designed against appropriate design temperatures and pressures and are manufactured and tested in accordance with appropriate engineering standards. Except for break-in requirements for maintenance or recovery from breakdowns, the LWMS are fully welded systems.
- Measures will be taken, so far as is reasonably practicable, to minimise leakages from pipework transferring radioactive effluents that are embedded in floors or walls.
- The LWMS control system includes monitoring of all the main process parameters (pressure, flow, temperature, tank levels, etc.) with appropriate alarms provided to the operators in the event of abnormal conditions.
- The LWMS control system includes level control for all tanks including appropriate interlocks to prevent tank overflows.
- All floor drains and bund sumps have leak detectors/alarms and pumps to recover spilled liquids into the LWMS.
- Bunding will be provided in line with UK regulatory requirements and industry best practice, including all tanks and where appropriate any other piece of equipment containing liquids. Bunding is provided at all external doors to LWMS buildings to prevent the spread of any spilt liquids to the outside of the buildings.

All potentially radioactive liquid wastes are collected in sumps or drain tanks at various locations in the ABWR and transferred to collection tanks in the RW/B [Ref-12]. The LWMS operates normally on a batch basis. Treatment of the liquid wastes is undertaken according to the type of impurity and chemical content in each waste stream, so as to provide the most efficient and economical process. With the exception of the LD aqueous waste stream, the waste streams within the LWMS are treated to enable as much of the liquid waste to be recycled within the ABWR [Ref-22]. The LD waste stream is likely to contain detergent impurities making it unsuitable for re-use, although effluent can be re-circulated multiple times through the LD system [Ref-22]. Treatment for re-use is a key function of the LCW and HCW systems. The treatment technologies in place have been selected and are designed to treat the liquid effluents so that they can be re-used within the UK ABWR. This key function also minimises liquid discharges to the environment (the sea) as far as practicable. It is noted that the LCW and HCW systems are radioactive waste treatment systems, and consequently designed for the treatment of radioactive materials. However, the treatment technologies employed are not specific for the removal of radionuclides and are also effective in managing any non-radioactive contaminants present.

Separate liquid effluent treatment systems exist for the HCW, LCW and LD discharge routes. There is no treatment of effluent directly within the CAD drainage system, although contaminated effluent can be diverted for treatment in the HCW system. Monitoring of the liquid effluent discharged from the LWMS system is undertaken at the discharge line, downstream from the Seal Pit. The discharge is monitored continuously for radiation. Grab sampling equipment on the discharge line means that sampling can be conducted to confirm that the water quality satisfies discharge criteria.

5.4.3.1 Treatment of LCW effluent

The treatment technologies within the LCW system consist of a filter and a demineraliser, with the system designed to ensure that the water quality meets the criteria for the CST and subsequent reuse in the plant. Recirculation and re-use of the LCW effluent ensures that there is no discharge from the LCW system other than via the HCW system [Ref-77]. An assessment of possible treatment technologies for the LCW system (demineralisers (ion exchange), reverse osmotic membrane and cross-flow filtration) identified that demineralisation with filtration was the preferred option for the treatment of the effluent discharged to the LCW system [Ref-77].

The purpose of the filtration stage is to remove insoluble contaminants, with the subsequent demineralisation stage designed to remove soluble contaminants. The performance of the LCW to remove soluble and insoluble contaminants has been demonstrated through operational experience and feedback on the filtration system. Analysis of samples taken from the inlet and outlet of the LCW demonstrates a decontamination factor (DF)[6] of approximately 100 (required DF value) is achieved typically by the LCW system. This high level of performance ensures that liquids are suitable to be reused within the UK ABWR [Ref-78].

Further details on the two treatment processes (filtration and demineralisation) are presented below.

- Filtration - Hollow fibre membrane filters are used to remove insoluble impurities in the LCW [Ref-77]. The crud removed in this filtration stage is transferred to the sludge storage tanks within the Rw/B.
- Demineralisation is the removal of soluble salts (substances present in ionic form) from aqueous effluents using ion exchange resins which retain certain substances. The resin and contaminants then become solid waste when the demineralisation medium is spent. Ion exchange resins are recognised as industry standard relevant good practice in the nuclear industry for the removal of soluble radionuclides and are used extensively on nuclear power plants in the UK and internationally [Ref-78]. The ion exchange media selected for use within the demineraliser (organic or inorganic) depends on the properties of the target ion, the presence of other competing ions in the feed stream, availability and cost [Ref-78]. Whilst the system is designed for the removal of radionuclides it is important to note that the ion exchange media used are not selective for radionuclides only and will remove non-radioactive soluble salts equally well. The design of the demineralisers in the LCW system is sufficiently flexible to allow a future operator to select the most appropriate ion exchange media.

5.4.3.2 Treatment of HCW effluent

The HCW system comprises an evaporator for removal of impurities followed by a demineraliser for the removal of residual soluble contaminants. Treated effluent is either transferred to the CST for reuse within the UK ABWR, or in limited circumstances (generally associated with maintaining the plant water balance), disposed of to the environment via the Seal Pit [Ref-78].

The evaporator in the HCW is effective at concentrating and containing the majority of the contaminants in the HCW effluent into a form that will enable the contaminants to be removed from the system as solid waste. However, some of the volatile contaminants are carried over from the evaporator with the distillate from this treatment stage. The purpose of the demineraliser is to provide a further treatment stage (termed ‘polishing’) to minimise the contaminants present before the treated effluent is discharged to the HCW sample tank.

Further details on the two treatment processes (evaporation and demineralisation) are presented below.

- Evaporation – by providing effective treatment and clean-up of the liquid effluent, the use of the evaporator allows a high proportion of the HCW effluent to be returned to the CST for re-use within the UK ABWR, thereby ensuring that discharges are minimised as far as reasonably practicable. Evaporators are standard components in Japanese ABWRs [Ref-78]. Evaporation leads to significant volume reductions compared with other techniques. Depending on the chemical composition of the liquid effluents and the evaporator type, a DF of 1,000 (required DF value) is achieved typically by the HCW system[7]. The IAEA report on the Handling and

[6] Decontamination factor (DF) is a measure of the effectiveness of a decontamination process.

[7] A review by Hitachi-GE of suitable treatment technologies for use in the HCW system, identified evaporation as providing the highest DF when compared with reverse osmosis membrane, ion exchange, ultra-filtration and micro-filtration [Ref-80].

Processing of Radioactive Waste from Nuclear Applications [Ref-79] describes how evaporation is used widely in the nuclear industry as an effective method for the chemical and radiological purification of liquid effluent.

- Demineralisation - the basis for the inclusion of a demineralisation stage is described in the section above (LCW). As with the LCW system, the demineraliser in the HCW system 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 [Ref-78].

A filtration stage in the HCW system is unnecessary as the evaporator retains solid substances in the concentrate [Ref-78].

The combination of these treatment technologies is effective in removing both inorganic and organic contaminants present in the effluents routed to the HCW system. Effluents are routed to the HCW system on the basis of them containing radioactive contaminants, or having the potential for radioactive contaminants to be present. The exception is effluent from the CAD system that arises from the drain down of closed loop cooling systems (such as TCW and RCW) located within controlled areas of the UK ABWR. This effluent is expected to be essentially free from radiological contamination (Section 5.3.3.1), but does arise from controlled areas within the UK ABWR. The effluent contains sodium nitrite (a corrosion inhibitor), and the effluent will only be generated during maintenance activities undertaken in outage periods. The demineraliser treatment stage in the HCW system will be effective in removing the sodium nitrite present.

The treated effluent is discharged from the HCW sample tank to the Seal Pit where it mixes with the cooling water discharge before release to the sea. The minimum volume of cooling water present (9,100 m^3/h) (Table 4.4-1) would result in a 79 fold dilution of the HCW treated effluent (assuming 115 m^3 per batch discharge).

The treated state (CST quality) of the discharge from the HCW sample tank means that potential impacts of this to the marine environment will be very low. There are no significant contamintants present, and dilution of the effluent in the cooling water is expected to result in any potential impact being negligible.

5.4.3.3 Treatment of LD effluent

The LD system processes wastewater originating from the laundry and the S/B showers and hand washing facilities [Ref-77]. Liquid effluent discharged into the LD system contains detergent, suspended solids and organic material, as well as potentially low levels of radioactive crud. As a consequence of this it is not suitable for re-use in the reactor system, and is therefore treated separately from the other waste streams [Ref-77].

The treatment technologies within the LD system are designed to manage and treat the specific types of contaminants present within this effluent stream. Treatment in the LD system consists of three filtration systems. These are a packed bed pre-filter, followed by an activated charcoal adsorption unit and finally a pre-coat carbon filter [Ref-77], as identified below. The three filter system achieves a DF of 300 (required DF value) for insoluble contaminants.

- Pre-Filtration - The pre-filter is a vessel with layers of hollow fibre blanket type material which acts as a coarse filter to collect hair and other larger sized suspended solids. The suspended solids are removed from the system as waste sludge together with the filter media, monitored and prepared for transfer to the dry solid low level waste (LLW) processing system.

- Activated Carbon Adsorption units – These are bed filters containing bead activated carbon (BAC), which adsorb organic impurities and trap the smaller suspended solids that pass through the pre-filters. The adsorbed impurities and suspended solids are removed from the system together with the (exhausted) activated carbon filter when the differential pressure becomes high. The activated carbon is retrieved, monitored and transferred into 210 litre drums for transfer to the wet solid LLW processing systems.
- Pre-Coat Carbon Filters - The pre-coated filters consist of an array of cartridges with a fabric 'sock' which is pre-coated in granular activated carbon (GAC), the purpose of which is to trap small-sized suspended solids. The waste sludge is removed from the system together with the filter media. The GAC is discharged into a collection drum and monitored. The drums are transferred to the wet solid LLW processing systems.

Following treatment through the pre-coat carbon filters, the treated waste water is collected in a sample tank, where a representative sample of the water is analysed to confirm that the residual level of radioactive contamination meets the criteria for discharge to the environment that will be defined in the EP-RSR Permit. Treated water which meets the discharge criteria for the LD system will be routed to the Seal Pit. If the treated water does not meet the discharge criteria, it can be routed back to the LD Collection Tank and the treatment process repeated (potentially multiple times) until the discharge criteria are met.

5.4.4 Treatment of Boiler Blowdown

The effluent generated from the boiler blowdown process is held in a dedicated tank for interim storage prior to disposal to the Seal Pit (as a batch or continuous discharge). The volume of boiler blowdown liquid effluent is 4.7 m^3 per day. Phosphate will be present at 3 ppm. As a worst case (Section 5.3.4), hydrazine is present at a concentration of 0.2 ppm.

Should only limited degradation of the hydrazine occur in the boiler water, then measures would be implemented to remove hydrazine present in the blowdown. This is possible through the addition of sodium hypochlorite[8] for example which would oxidise the hydrazine present to nitrogen, water and sodium chloride.

It is noted that the chemicals identified to manage water quality within the auxiliary boilers at this generic design stage may change at the site-specific stage depending on the operating strategy for the UK ABWR.

5.4.5 Treatment of Effluent from the PWTF

The liquid effluent from the PWTF is generated on a continuous basis, held in an interim storage tank and then discharged to the Seal Pit. The quantity of effluent generated is equivalent to 50% of the volume of townswater feedwater (Section 4.3). The PWTF will produce up to 450 m^3 of purified water per day, and up to 450 m^3 of effluent per day. The effluent will effectively be concentrated townswater containing the same chemical constituents as the townswater feedwater, but at double the concentration. No chemicals other than those present in the townswater feedwater will be present in the effluent, and no treatment of the effluent is proposed before discharge to the Seal Pit.

Following discharge into the Seal Pit, the 450 m^3 per day of effluent will mix with the cooling water discharge (Section 5.4.7.3), and the smaller volume discharges from the other processes. The lowest volume of cooling water discharged is during an outage period when the TSW and RSW systems are operating. The lowest volume of seawater discharged (9,100 m^3/h (218,400 m^3 per day)) (Table 4.4-1) is

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[8] It is noted that sodium hypochlorite is identified as a candidate biocide for the management of biofouling in the UK ABWR. This chemical will therefore be present in the cooling water discharged to the Seal Pit, and the sea.

three orders of magnitude greater than the discharge from the PWTF. Significant dilution of the PWTF discharge (4.9×10^2 fold dilution) would be expected before release to the sea.

5.4.6 Treatment of Rainwater

Precipitation (rainwater) falling within the UK ABWR site is treated according to whether it falls inside or outside the inner fence. Precipitation falling within the inner fence drains to the Seal Pit.

As detailed in Section 5.3.6, rainwater falling outside the inner fence may be released directly to the sea and not go to the Seal Pit. Appropriate measures will be in place on these discharge routes so that any accidental spills of hazardous chemicals within the site that enter the rainwater drainage system can be retained within the drainage system and not released to the environment. Measures may include hydrocarbon interceptors and containment areas to enable suspended solids and hydrocarbons to be removed. The scale of the measures implemented will depend on the worst case quantity of rainwater or firewater that may need to be contained. As this is determined by the site-specific aspects then the design of the rainwater/firewater drainage system (and associated treatment systems) will be addressed at the site-specific stage.

5.4.7 Assessment of Impact to the Receiving Environment

The discharge criteria to the sea established for the UK ABWR will be designed to meet the relevant environmental quality standards (EQSs) (where available) for the contaminants present, so that the EQS thresholds are not exceeded in the receiving water (the sea). The most up to date EQS values for England and Wales are given in The River Basin Districts Typology, Standards and Groundwater Threshold Values (Water Framework Directive) (England and Wales) Direction 2010 [Ref-25]. The EQS (from the Dangerous Substances Directive) for any dangerous substance not identified under the Water Framework Directive (WFD) will continue to apply until the Dangerous Substances Directive is repealed.

5.4.7.1 Assessment Methodology

The assessment methodology applied follows the approach set out in the EA's Horizontal Guidance Note H1 ('H1'). The type of assessment undertaken is determined by whether the discharge is defined as 'simple' or 'complex' [Ref-26]:

- Simple discharges - defined as continuous discharges over time, where all the components have been identified, the toxicity and environmental effects of individual chemicals is documented and the combined effects can be estimated by simple addition. The concentration of individual contaminants is determined both at end of pipe immediately prior to discharge to the sea (the discharge concentration (DC)), and also in the receiving environment following dilution (using a near field dilution factor of 0.2), to give a process contribution (PC) (µg/l) to the receiving water. The PC values are then compared to the relevant EQS. If the PC is <4% of the EQS maximum allowable concentration (MAC) or the EQS annual average (AA), then the contaminant is screened out of further consideration.
- Complex discharges - defined as discharges where there is no available information on the safe levels or aquatic toxicology of the likely combination of chemicals in the discharge, even if there is information on the individual chemicals. The complex discharge approach is also applied if the receiving water is especially sensitive or if the simple approach has not allowed a discharge to be 'screened out' on the basis of negligible impacts. Sensitivity of the receiving water would be identified at the site-specific stage. As with the simple discharge approach, the concentration of individual contaminants is determined both at end of pipe and in the receiving environment following dilution, to give a PC (µg/l) to the receiving water. The PC values are compared with relevant EQS (or other environmental quality criteria if EQS is not available). The methodology may also require an assessment to be made on whether the discharge causes >10% deterioration

in existing background concentrations. It may also require a direct toxicity assessment (DTA) to be made.

The assessments of both simple and complex discharges have a site-specific component as a consequence of their consideration of the characteristics of the receiving environment, and can therefore only be completed at the site-specific stage.

For the purposes of the GDA assessment, it has therefore only been possible to undertake the simple and complex discharge assessments up to the determination of the concentration of contaminants at end of pipe (i.e. in the final discharge). Only those substances for which there is an EQS value have been considered in the impact assessment at GDA stage. The impact of other substances (for which an EQS is not available) will be considered in the site-specific Environmental Permit application.

5.4.7.2 Chemicals Assessed

As described (Sections 5.3.1 to 5.3.6), only a small number of non-radioactive named chemicals are expected to be present as contaminants in the liquid effluent systems in the ABWR. Of these, only the following have been identified as having the potential to be discharged to the sea. The other chemicals identified in the preceding sections are removed from the liquid effluent streams in the treatment process and captured within solid waste streams:

- Cooling water systems (TSW and RSW) – ferrous ions and/or biocide.
    - Ferrous ions – the maximum concentration present is 0.03 ppm for three months during commissioning, and for one month after the cleaning of the heat exchanger tubes. The concentration of ferrous ions in the heat exchangers during normal operation is 0.01 ppm (Section 4.4.2). Discharge rate under normal operation from the TSW and RSW systems is 7,400 m^3/h and 10,800 m^3/h respectively (Section 5.3.1).
    - Biocide (assessed on the basis of sodium hypochlorite) – sodium hypochlorite and degradation products (termed total residual oxidants (TRO)). When injected into water, the chlorine in the sodium hypochlorite forms a number of residual oxidising species including hypochlorous acid (HOCl) and free chlorine, as well as small volumes of by-products such as chloramines and bromoform ($CHBr_3$). The degradation of these by-products occurs at varying rates and depends on site-specific factors primarily the level of mixing (due to turbulence) and relative concentration.
- NSD – corrosion inhibitor (nitrite) present at a maximum concentration of 300 ppm (Section 5.3.2.2.1). Normal discharge rate from the NSD system estimated at 24 m^3/day, with a maximum discharge of 240 m^3/day.
- CAD – corrosion inhibitor (nitrite) present at a maximum concentration of 300 ppm (Section 5.3.3.1.1).
- LD – detergent. Total of 750 litres of detergent used in the laundry system annually. Discharge from the LD system is approximately 2,240 m^3/year (Section 5.3.3.4). Some of the detergent will be retained within the LD treatment system (on the activated carbon columns) and would not be discharged. The proportion retained is not known at this stage. To assess a worst case for the detergent, no retention is assumed to occur, resulting in 750 litres of detergent released to the Seal Pit annually. The decision on the detergent to be used at the site-specific stage will be made by the site operator. For the purposes of GDA, the detergent used is assumed to be a biodegradable commercial product, such as Manoxol OT. This is an anionic-based surfactant, which undergoes almost complete biodegradation in seawater in 17 days [Ref-83].
- Boiler blowdown – phosphate and potentially hydrazine (assuming no degradation of this chemical). It is noted that hydrazine is not expected to be present as it will have been either degraded within the boiler water (and not discharged into the blowdown), or will have been removed from the blowdown through treatment with sodium hypochlorite in the blowdown

(Section 5.4.4). Assessment of the potential impact from hydrazine is included only as a worst case therefore. The presence of sodium associated with phosphate (assuming the phosphate used is sodium phosphate) is not assessed because the receiving environment for the discharge is seawater. Any sodium discharged will be negligible compared with the concentration in the receiving marine environment.

- Effluent from the PWTF – contains the chemicals present in the townswater feedwater to the PWTF but at concentrations double that present in the townswater. The specific chemicals present (and their concentrations) will depend on the characteristics of the townswater supply. This will be determined at site specific stage. Potential impact will be negligible as a consequence of the effluent being townswater (at double potable supply concentration), and having undergone significant dilution within the cooling water prior to discharge to the sea.

Other non-specified contaminants will be present in the discharges from the SWSD, NSD and LWMS systems, in the form of suspended solids and COD.

5.4.7.3 Dilution of process effluents in the Seal Pit

Process effluent discharged to the Seal Pit will be diluted within the cooling water flow (comprising the discharges from the CW, TSW and RSW systems). The discharges from the systems during routine operation and outage are summaried in Table 4.4-1. The lowest cooling water flow through the Seal Pit, resulting in the lowest (and therefore worst case) level of dilution is 9,100 m^3/h (RSW and TSW flows in outage) (Table 4.4-1).

5.4.7.4 Assessment of Impact to the Marine Environment

Of the named chemicals listed in Section 5.4.7.2, EQS values are available for iron (as representative of the ferrous ions discharged), ammonia and chlorine (as TRO):

- Iron – 1 mg/l annual mean concentration of dissolved iron for coastal waters [Ref-25].
- Chlorine (as TRO) – 0.01 mg/l [Ref-81][Ref-26].

There is no EQS reported for hydrazine. An NOEC (no observed effect concentration) of 0.5 µg/l is reported (derived from a review of ecotoxicity data) [Ref-26]. The Environment Agency report [Ref-26] reports the most stringent USEPA criterion for phosphate as 10 µg/l to limit algal growth and eutrophication.

5.4.7.4.1 Biocide (sodium hypochlorite)

By definition, a biocide chemical such as sodium hypochlorite will have a negative impact on the marine organisms which are exposed to it. The impact posed is a consequence of the exposure of marine organisms to both the biocide chemical, and also to residual oxidising degradation products. When injected into water, the chlorine in the sodium hypochlorite forms a number of residual oxidising species including hypochlorous acid (HOCl) and free chlorine, as well as small volumes of by-products such as chloramines and bromoform ($CHBr_3$). These by-products (termed total residual oxidants (TROs)) undergo degradation in seawater, with half-lives in seawater ranging from nine to twenty-six hours [Ref-26]. The specific rate of degradation of each by-product depends on site-specific factors, primarily the level of mixing (following release of the TRO into the sea) and the concentration of sodium hypochlorite dosed into the cooling water system. The relatively rapid degradation expected, coupled with the significant dilution following discharge from the outfall into the sea, will reduce the potential impact posed by the TRO compounds to the marine environment.

The environmental quality standard (EQS) reported for chlorine (as TRO) in the marine environment is 0.01 mg/l [Ref-81][Ref-26]. Should sodium hypochlorite be used as the chemical biocide for the UK ABWR, the dosing strategy would be designed so that the sodium hypochlorite is dosed into the CW, RSW and TSW systems at a level that is sufficient to achieve both the required management of bio-fouling, and also not to exceed the 0.01 mg/l EQS for TRO at the edge of the mixing zone following the discharge of the cooling water into the sea. Such a dosing strategy (which will be developed at site specific stage) is expected to result in a concentration of 0.1 mg/l TRO at the outfall. Potential impacts to the marine environment will therefore be limited to those that could be caused by a maximum concentration of 0.1 mg/l TRO (at the cooling water outfall).

The significance of site specific factors in the dosing strategy (water temperature, type of marine species present and population densities for example) mean that the identification of a detailed dosing strategy is not appropriate for the generic site. This will be addressed at site specific stage.

The biocide dosing strategy developed at site specific stage will be designed to ensure that effects on the wider marine environment are acceptable. One measure of the potential effect on the marine environment is the size of the mixing zone within which the EQS value (for TRO) is exceeded. The cooling water outfall for example can be designed to promote either high initial mixing (which may result in higher impacts to the seabed, but a smaller surface mixing zone), or to take advantage of the buoyancy of the cooling water discharge to avoid impacts to the seabed but resulting in a larger surface mixing zone.

As a consequence of dilution and degradation, the area of seawater exposed to a concentration of TRO in excess of the EQS value (0.01 mg/l) within the mixing zone is likely to be limited to the immediate vicinity of the discharge point. Fish (and other mobile species) are likely to move away from such areas of toxicity, and dilution of the TRO compounds will reduce the exposure time of non-motile organisms (such as plankton). The toxic effects of the TRO vary according to the exact chemical species present. The formation of particular compounds is dependent on temperature and pH of the seawater [Ref-26]. As these factors are site specific it is not possible to make a more detailed assessment of the impact posed by TRO compounds at this generic stage.

The size of the mixing zone will be influenced by local conditions such as water depth and currents, the design and location of the outfall, and the dosing strategy. It will therefore be determined at site specific stage through modelling, impact assessment and agreement with regulators.

5.4.7.4.2 Boiler blowdown

The discharge of the boiler blowdown effluent as part of the cooling water discharge provides a very significant dilution of any boiler blowdown chemicals prior to discharge to the sea. As a worst case, the 4.7 m^3 of boiler blowdown is assumed to be discharged to the Seal Pit as a single batch during an outage period. The minimum level of dilution of the boiler blowdown will occur during outage when only 9,100 m^3/h of seawater is discharged (Table 4.4-1). A much higher level of dilution will occur during normal operation when 203,000 m^3/h of seawater is discharged (Table 4.4-1).

- Phosphate – present at 3 ppm in blowdown. Dilution in 9,100 m^3/h of cooling water (Table 4.4-1) results in a predicted concentration of 1.5 µg/l at the cooling water outfall. This concentration is below the 10 µg/l value set by the USEPA as the phosphate concentration required to limit algal growth in the water and subsequent eutrophication.
- Hydrazine – worst case concentration of 0.2 ppm in blowdown (assuming no degradation of the hydrazine in the boiler water, and therefore the level in the blowdown is equivalent to that dosed into the boiler feedwater). Dilution of the 4.7 m^3 of boiler blowdown in 9,100 m^3/h of cooling water (Table 4.4-1) results in a predicted concentration of 0.1 µg/l at the cooling water outfall. This concentration is below the 0.5 µg/l NOEC value reported for this chemical.

It is noted that outside the outage period (i.e. during normal operation) the level of dilution that occurs will be 22 times greater, as the cooling water discharge will be 203,000 m^3/h (Table 4.4-1). This will reduce the concentrations of the boiler blowdown chemicals at the outfall below those presented above, with a concomitant reduction in potential impact.

5.4.7.4.3 Iron

The assessment is determined by comparison of the DC and PC of each chemical against the relevant EQS value. In determining both the DC and PC values, dilution, as a consequence of the effect of the combination of the process streams (from the TSW and RSW systems (total discharge of 18,200 m^3/h)) has been assumed to occur.

DC and PC values have been calculated as follows:

$$DC = \frac{(\text{Annual flow} \times 10^6 \times 10^3)}{(\text{discharge flow} \times 365 \times 24 \times 3600 \times 10^3)}$$

$$PC = \frac{(\text{Annual flow} \times 10^6 \times 10^3)}{(\text{discharge flow} \times 365 \times 24 \times 3600 \times 10^3)} \times 0.2$$

The absence of information (at generic design stage) on the quantity of ammonia that may be present in the boiler blowdown effluent means that it is not possible to calculate the annual flow figure for this chemical. Consequently, DC and PC values cannot be calculated for ammonia at this stage.

Table 5.4-1: Assessment of DC and PC against EQS Values

Chemical	Annual flow (kg)	DC (µg/l)	PC (µg/l)	EQS (µg/l)	DC/EQS (%)	PC/EQS (%)
Iron (0.03ppm)	4783[A]	2.69[B]	0.54	1000	0.27	0.05

[A] – The annual flow figure presented is based on the maximum concentration of 0.03 ppm of ferrous ions present in the RSW and TSW systems. This figure (3,363 kg) is therefore an overestimation of the quantity of iron that could be released from the UK ABWR. Ferrous ions are only dosed into the TSW and RSW systems to achieve this concentration for three months during commissioning, and for one month following maintenance. Whilst dosing occurs in normal operation, it is at the lower concentration of 0.01 ppm.

[B] – Discharge concentration is the concentration in the discharge from the TSW and RSW systems. This is a worst case as further dilution would be expected in the total cooling water discharge before release into the sea.

The PC presented in Table 5.4-1 for iron is <4% of the EQS. Therefore the release of iron (as the worst case concentration) is screened out of the impact assessment.

5.4.7.4.4 Hydrazine

A full assessment has not been undertaken for hydrazine at GDA stage on the basis that hydrazine is not expected to be discharged as a result of degradation within the boiler water, or removal from the blowdown through treatment with sodium hypochlorite (Section 5.4.7.2).

5.4.7.4.5 Detergent

A decision on the detergent to be used will be made at site specific stage by the site operator. At GDA stage information is presented on a typical detergent that could be used, and the potential impact posed by that detergent to the environment. A detergent such as Manoxol OT, is an example of a typical commercially available detergent that would be suitable for use in the laundry system at the UK ABWR.

Manoxol OT is an anionic surfactant based detergent. The active ingredient (butanedioic acid, sulfo-1,4 bis(2-ethylhexyl) ester, sodium salt) is present at a concentration of up to 75%, and is reported to have no toxic effects to the environment or aquatic organisms (no toxicity or dangerous to the environment hazard categories are assigned to this chemical)[9]. This detergent is reported to undergo relatively rapid biodegradation in aquatic environments [Ref-82], with almost complete biodegradation in seawater in 17 days [Ref-83]. Degradation products that arise during biodegradation are also reported not to be toxic [Ref-82].

The discharge of the laundry drain effluent into the seal pit prior to release to the marine environment, means that this effluent will be subject to significant dilution. This will further reduce the potential impact posed. The lowest dilution will occur during an outage period, which is also the period of greatest discharge of laundry effluent (as a result of more people in the controlled areas at that time). However, even assuming that all 750 litres of detergent was discharged during a single outage period then the 750 litres of detergent would be subject to an $8x10^6$ fold dilution in the cooling water discharged during the outage period.

As a consequence of its limited persistence in the environment (as a result of biodegradation), and no reported toxicity, a detergent such as Manoxol OT in the discharge from the LD system is assessed to cause negligible effects to the marine environment.

5.5 Identification of Options for Beneficial Use of Waste Heat

5.5.1 Introduction

For the purposes of the GDA it is assumed that the site location is coastal and that the design will use a once-through seawater cooling system. This is regarded as the BAT in the BREF Report [Ref-27].

There are three circuits using seawater to remove heat from various auxiliary plant and equipment returning it to the sea via a common cooling water outfall. The three circuits are described in Section 4.4.2 and include:

- CW - removing heat from the main power cycle via the main condenser.
- RSW - removing heat from various auxiliary heat exchangers and equipment within the R/B.
- TSW - removing heat from various auxiliary heat exchangers and equipment within the T/B via the TCW heat exchangers.

Seawater will be abstracted via a common inlet structure and passed through the three cooling circuits. The returning water from the three circuits enters a common Seal Pit prior to discharging back to sea.

Table 5.5-1 summarises the data in relation to the design of the ABWR cooling water system.

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[9] Value presented in a safety data sheet (SDS) from a commercial supplier for Aerosol OT (a synonym for Manoxol OT).

Table 5.5-1: Summary of the ABWR Data - Cooling Water Design Parameters

Circuit	Flow Rate - m^3/h (m^3/sec)	Temperature Uplift under normal operation (°C)	Calculated Energy Transfer (MW)
CW	184,800 (51.3)	12	2,483
RSW	10,800 (3.0)	4.4	55
TSW	7,400 (2.1)	5.1	43
Total	**203,000 (56.4)**	**-**	**2,581**

5.5.2 Options for Waste Heat Utilisation

Condenser circulating water is used to condense the low-pressure steam, thus removing the 'waste heat' from coal-fired, oil-fired, combined cycle gas-fired, and nuclear plants that operate on the Rankine cycle. The condenser circulating water is heated while passing through the plant's condenser and discharged into the environment. In open systems, the heat in the condenser circulating water is discharged to lakes, rivers, or oceans, and in closed systems, it is discharged directly into the atmosphere, typically through cooling towers.

A consequence of the second law of thermodynamics is that any electric power plant that is operating on the Rankine cycle will typically reject approximately 60% to 70% of the heat that is added to the cycle through the condenser to the ambient environment in order to complete the cycle. The temperature of the waste heat exiting power plants, while too low for electric power generation, may be suitable for other purposes such as heating greenhouses and aquaculture (fish farming) facilities, particularly those power plants that reject this waste heat directly to the atmosphere via cooling towers due to the marginally higher rejection temperatures. If heat was intended to be a bi-product of a Rankine cycle plant, as in a Combined Heat and Power Plant (CHP), then the temperature of the waste heat can be raised to higher levels, although this reduces the electrical output and efficiency of the power plant [Ref-28][Ref-29][Ref-30][Ref-31].

It has been determined that around 2,581 MW of waste heat will be generated in the form of low grade heat with a mean temperature of 23°C. At this temperature, the heat is regarded as very low grade, limiting its recovery and application.

To put this quantity of energy into perspective, the heat output during a 6 month heating season[10] would be in the region of 22,600 GWh/y (assuming 2,581 MW is produced continuously over the year). In very approximate terms, this is equivalent to the thermal energy (GWh) required to heat around 750,000 homes during the UK heating season, leaving a similar amount of energy available for other uses during the non-heating season. Between 2008 and 2012, the normalised average natural gas consumption per household was ~15,200 kWh/y [Ref-32]. When placed into this context, both the potential opportunity and challenge of distributing and utilising this amount of heat can be appreciated.

If the waste heat can be recovered and used to offset conventional heat generation from fossil fuels it will produce a favourable carbon benefit and potential financial savings to the end user whilst also reducing the environmental impact of the power plant. Utilisation of this waste heat could also offset the requirement for more power generation required for decarbonising the UK's heating demands.

Heat can be either used directly, or converted into electricity. As this heat is already the by-product of electricity generation this report has not considered in any depth, the potential for further generation because it is assumed that the ABWR has been designed to maximise the production of electricity resulting in the production of low temperature waste heat thereby maximising electrical generation efficiency.

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[10] The heating season refers to the cooler months of the year during which a typical household would use heating.

Since the temperature of the waste heat has already been reduced to the lowest possible level, the task of utilising the waste heat is quite challenging. In addition, space heating for personal comfort is only required during the cooler months (or heating season), which further limits the economic case for heat recovery for comfort heating. As illustrated above, the sheer quantity of heat is also a factor, in that whilst there are potential opportunities to utilise the heat, e.g., aquaculture (fish farming), the demand from this activity (in the context of the UK) would be relatively small and it may not be economically justifiable to develop a heat recovery infrastructure for this purpose alone. In addition, if users are reliant on heat distributed from power plant, consideration has to be given to installing back-up heating systems should the heat from the power station be unavailable for any reason, further increasing the required infrastructure and overall project costs.

By increasing the temperature of the available waste heat in order to increase the quality of the thermal energy, the power production in the power station would be reduced, creating a trade-off between reduced electricity generation versus availability of higher grade heat which has greater economic potential to be usefully recovered than the low grade heat described above.

Examination of the use of this heat should therefore consider:

- The recovery of the low temperature heat.
- Increasing the temperature of the cooling water with subsequent cascading of its utilisation as the quality degrades.
- Raising the temperature of the media through the application of heat pump technology and integration of heat networks / energy parks.

5.5.2.1 Crop Growing (Glasshouses)

There are increasing pressures on the horticultural industry, not least population growth. However, competition from imports (Holland, Spain, Canaries, etc.), and pressure from customers, including the major supermarkets, is also driving the need to improve yield and quality, in addition to an increasing drive for locally sourced fresh food and reduced household grocery costs. As a result of these commercial pressures, the area cultivated in the UK for glasshouse crops has reduced [Ref-33].

Heating is often used in large commercial glasshouses to enhance plant growth. Typically, hot water is piped throughout the glasshouse in un-insulated metal pipes that radiate the heat. A water temperature of 60 to 90°C is generally utilised and the return temperature will depend on the amount of heat removed from the circuit. A typical glasshouse will have an annual heat demand of between 175 and 675 kWh/m^2 (subject to intensity of cultivation and crop type) [Ref-34], for example:

- Energy intensive edible crop production, e.g., tomatoes, cucumbers and peppers, which require ambient temperatures above 18°C together with humidity and carbon dioxide (CO_2) control.
- Energy intensive ornamental crop production, e.g., chrysanthemum, begonia and poinsettia require ambient temperatures above 18°C together with humidity control, CO_2 enrichment and supplementary lighting.
- Energy low-intensive edible crop production, e.g., lettuce production, requiring lower growing temperatures and less complex environmental controls.
- Energy extensive ornamental crop production, including crops that are grown at low temperatures (<15°C heating temperature), such as bedding plants, etc.

Table 5.5-2: Energy Use Benchmarks - kWh/m^2

	Edible Crops		Ornamental Crops	
	Intensive	Extensive	Intensive	Extensive
Typical	675	250	450	175

Extremely large glasshouse complexes are required to utilise the significant amount of waste thermal energy that is generated from a typical power station. Such complexes would need to be justifiable primarily on market value of the products, which would dictate the types of crops / plants grown. To put this in perspective, on the basis of utilising 2,581 MW continuously throughout the year, the total area of glasshouses required would range between approximately 3,300 hectares (ha) and 12,900 ha (subject to intensity of cultivation and crop type). At the higher of these figures, this equates to an area of 130 km^2 (greater than the area of Bristol). Clearly, sinking heat into glasshouses alone would require a significant development to use even a small proportion of the heat available.

Direct contact, under soil/floor and forced air (dry) heat exchangers have demonstrated some capability for maintaining the temperature above 14°C [Ref-35]. High humidity associated with direct contact heat exchange may create problems and necessitate disease control.

Soil or floor heating systems are only considered viable in moderate climates for production of cool season crops, and in colder climates, only as a secondary heat source in glasshouses, although cheaper energy may turn this viewpoint around. In relation to field crops and use of under soil heating pipes, outcomes include quicker emergence and faster early growth of field and vegetable crops, although if the process brings the crop on too early, this may subject it to frost damage and/or can reduce hardiness. Therefore, careful selection of crops is essential [Ref-35].

An alternative method of heating glasshouses commonly used in Europe takes heat from gas fired CHP, with the CO_2 in the exhaust gases used to enhance crop growth as the plants absorb CO_2 [Ref-35]. This benefit would not be available from heat associated with a nuclear plant so growers may still chose to burn fossil fuel to generate the required CO_2. This could form the primary heat source with waste heat from the power plant acting as the secondary under soil/floor heating.

Consideration may also be given to maintaining environmental conditions for livestock. Whilst there is little useful benefit for beef and dairy cattle, rearing pigs and poultry broiler production may offer a heat sink as these can demand air temperatures of 10 to 24°C [Ref-35].

5.5.2.2 Aquaculture (Fish Farming)

Fish are an important source of food for people around the world. Fish can be either caught wild or farmed, a practice known as aquaculture.

As wild fishing stocks collapse through over-fishing, fish farming is growing rapidly as an industry. In 1970, only around 5% of the fish eaten came from farms [Ref-36]. Today half of the fish eaten is farmed. The species raised in fish farms include salmon, trout, cod, carp, catfish, sea bass, tilapia, and others. The vast majority of Atlantic salmon and rainbow trout are farmed intensively in fish farms [Ref-36].

Most of the existing UK finfish aquaculture industry is based upon open, flow-through systems where natural water bodies provide a clean water supply, and remove and assimilate wastes. Such culture systems have been criticised as they are dependent upon this natural supply, which if intensive, can incur an environmental cost on the supplying / receiving environment [Ref-37].

An alternative model for intensive finfish production is closed Recirculation Aquaculture Systems (RAS). In RAS, water is recirculated and technology is used to remove wastes and maintain oxygen levels. RAS are often perceived as having strong ’green’ credentials and RAS products are promoted as sustainable by environmental organisations such as Seafood Watch and Greenpeace because, as closed systems, they abstract little, if any, water from natural water bodies (once operational), produce minimal effluent, with readily managed waste streams, and they reduce the potential environmental impacts from escapees and pathogen release [Ref-37].

RAS also offers many potential benefits to the producer and supply chain:

- Control of the fishes' environment allows consistent and predictable production, essential for modern food production.
- Removal of the dependence on a natural, clean, flowing water supply eliminates the potential effects of seasonal variations (e.g., floods, droughts), widens the potential locations, and enables farms to be located closer to markets.
- Improved bio-security in closed systems reduces the risk of pathogen ingress and disease outbreaks.
- Closed systems eliminate losses due to predators.
- Containment within buildings aids temperature control, allowing all year round production.
- Heating allows alternative tropical fast growing species to be farmed.

Despite these apparent benefits, RAS may still attract criticism due to high energy usage, its associated carbon impacts and for ethical reasons. There is increasing recognition that most fish have highly developed senses and are said to be capable of feeling pain, fear and stress and through scientific discovery have been found to have long-term memories and social structures [Ref-36]. RAS are typically intensive systems, which may be viewed as 'factory farms'. Fish in fish farms are reared in large numbers in densely stocked tanks or enclosures in rivers, lakes or at sea in sea-cages. Many farmed fish are fed largely on wild fish - this is regarded as unsustainable and adds to the welfare concerns about how wild fish are caught and killed [Ref-37].

Over the last 10 years there has been a notable increase in both the number and size of land-based, warm-water RAS farms in England and Wales. In 2000 there were a couple of small scale farms, but a decade later there are approaching twenty farms which vary in scale from the production of 10 to 1000 t/y. [Ref-37]. These new farms represent a diversification in the UK aquaculture industry, and thereby help strengthen the UK's seafood security. However, despite the optimism surrounding RAS, a notable proportion of businesses have gone into administration. Various potential factors have been suggested anecdotally as contributing to the recurrent failure of commercial RAS in the UK, including high running costs, of which the cost of heating will be a factor [Ref-37].

Heating can obviously be delivered in numerous ways; space heaters are used by the majority of sites as it is generally considered more economical to heat the entire unit rather than just the water. This assumes that the building is well insulated. The space to heat is therefore a factor to consider in the initial design: there should not be an excessive space (air volume) to heat, although there should be sufficient exchange to prevent CO_2 build-up [Ref-37].

5.5.2.3 Heating of Road / De-icing Airport Runway Surfaces

It may be possible to use the low grade heat directly with the current low temperature cooling water to prevent ice and frost on road or airport runway/aircraft parking stand surfaces.

5.5.2.3.1 Under-Road Heating

This would require an extensive under surface heating network and there may be limitations for this application in relation to the distance between the road(s) and the ABWR. As a minimum, the waste heat could be used to heat the access roads around and into the NPP. The benefits of under-road heating include:

- Providing ice and snow free roads - safer roads and reducing accidents.

- Reduce reliance on expensive gritting machinery and salt.
- Reducing salt pollution to the water table.
- Reduce winter journey times.
- Reduce freeze-thaw damage of road surfaces, minimising potholes and increasing the life of the surface - thereby reducing maintenance costs.

The Transport Research Laboratory (TRL) completed a 2 year trial in 2007, on a section of the M1 motorway using a patented technology, called Inter-seasonal Heat Transfer (IHT) [Ref-38]. This process utilises the fact that black asphalt can reach temperatures 15°C higher than ambient in the summer through solar gain. In IHT, a series of water filled pipes are laid beneath the surface of the road to capture the solar heat in summer, storing this heat in thermal banks (at ~ 7 m below ground, the temperature is stable all year round at around 10°C and IHT can raise this to 25°C in summer months). In winter, this heat is then used to prevent the road surface temperature above from dropping to freezing point. Whilst utilising waste heat from the ABWR would not require the collection of heat and its storage, the application of under-road heating has shown some potential. In addition, the temperature uplift potential of the cooling water in warmer months may offer additional benefits such as increasing the output temperature from heat pumps.

Whilst the application of this approach is limited, a small town in Michigan (USA) in 1988 [Ref-39], installed an extensive network of pipes through which warm water (waste heat) from a nearby coal fired power station was pumped, maintaining snow and ice free streets and pavements in the downtown area during the winter.

5.5.2.3.2 De-icing at Airports

Heathrow operates up to 98% of capacity. Therefore, any delays create knock-on effects and cancellations. British Airport Authority (BAA) put its snow and ice disruption cost at £25 million in December 2010 [Ref-40], and British Airways lost £50million. The key problem is not just snow, which can be cleared by snow ploughs, but ice. Ice bonds to the ground surface, compromising the braking ability of aircraft and damaging the surface through freeze-thaw expansion and contraction.

Often expensive and hazardous chemicals are used (grit and salt cannot be used as they can cause damage to engines) [Ref-40], and if these fail more powerful de-icing treatments are required. Ice problems are significant on aircraft parking stands where it is more difficult to clear the snow and ice where aircraft are already parked. Introducing under runway heating for a busy airport may be expensive in relation to lost business, but its application may be more feasible for parking stand areas.

However, it is unlikely that the ABWR will be located within in any reasonable proximity to an airport as a result of safety issues.

5.5.2.4 Heat for Algae Bio Diesel Growth

Algae are simple aquatic plants that range from single-celled microalgae to large seaweeds. Algae can harvest the power of the sun absorbing carbon dioxide through photosynthesis and convert this into biomass, including oil. Many species are fast growing and more productive than land plants per unit area. This makes them an important part of the carbon cycle and they are able to produce complex molecules, such as hydrocarbons and carbohydrates [Ref-41].

Research is being undertaken to uncover novel microalgal compounds that could provide alternatives to those obtained from petrochemical sources. There are a wide range of bioenergy products that can be obtained from culturing algae including biomass for combustion to produce heat and electricity, fermentation to produce bioethanol, biobutanol or biogas, oil for conversion to biodiesel or even possibly algal synthesised biodiesel. Some microalgae have unique abilities such as being able to produce hydrogen gas which can be used in fuel cells to produce electricity. Others, such as cyanobacteria, have been suggested may be used in solar panels to generate electricity directly [Ref-41].

Algae require very nutrient rich environments, often toxic to other plants, so they could be used for treating ‘waste waters’, from a range of industrial and agricultural sources [Ref-42]. At a small scale, recycling nutrients from waste water could potentially provide some of the nutrients required by the algae, and there may be some scope to combine fuel production and waste water remediation.

Microalgae can be grown in large bioreactors or open raceways and continually harvested, unlike crops. One of the benefits of algae production is that it could use marginal land or sea, thereby minimising competition with food production. Algae can be grown using water resources such as brackish-, sea-, and wastewater unsuitable for cultivating agricultural crops [Ref-42].

Algae production requires a number of energy demanding processes which include the energy required for drying and de-watering the produced biomass. Using waste heat to dry the biomass is one strategy that might improve the overall carbon balance of the process [Ref-42].

Solar radiation is one of the most important factors influencing algal growth and to achieve high levels of production throughout the year, the culture of algae on a large commercial scale has so far been restricted to sunny climates, where there is little seasonal variation. For this reason, the application in the UK may be somewhat limited with the current strains of algae that are available, although waste heat from industrial processes could be used to warm ponds and increase growth rates [Ref-41].

5.5.2.5 Desalination

Although water covers 75% of the earth’s surface, only 3% of it is potable. Increasing population raises the pressure on limited water resources and increases the demand for technologies that can provide potable water. More than 7,500 desalination plants operate worldwide, with two-thirds of them in the Middle East, where there often is no other alternative for freshwater. The technology is less common in North America, where residents get less than 1 percent of their water from desalination plants, however, as the populations increase in cities and towns, desalination has been proposed as one solution to meet the demand for freshwater [Ref-43].

Here in the UK, whilst water is not a scarce commodity, there are increasing stresses on water treatment companies and the requirements to supply large volumes of potable water to cities and large conurbations.

Most commercial desalination plants now use either distillation or reverse osmosis. Distillation involves boiling and evaporating salt water and then condensing the vapour to produce freshwater. In reverse osmosis, high-pressure pumps force salt water through fine filters that trap and remove waterborne salts and minerals [Ref-43][Ref-44].

Boiling the vast amounts of water needed for the distillation process requires large amounts of energy. Using low grade waste heat would not only reduce the operating costs but would also be more sustainable. Reverse osmosis uses less energy but has other problems, including mineral build-up clogging the filters, causing plants to shut down, plus the cost of replacing membranes is high.

The first large-scale desalination plant in the UK opened in 2010 in Beckton on the River Thames in London, demonstrating the water stress in one of the UK's most populated region. This area receives less rainfall per person than Istanbul, Dallas or Sydney. Thames Water spent £250 million building the plant and associated pipework and said they intend operating the plant at times of drought, when it can supply up to 1 million people. Opponents have claimed that the plant will use too much energy and the company should be doing more to stop leaking pipes and reduce the average water use of customers by installing more water meters and better promotions. Thames Water has suggested that they are considering alternative ‘green’ fuels to supply the energy required. Some have speculated that Thames Water could connect the desalination plant directly to the adjacent Beckton sewage treatment plant, to produce recycled water. The recycling process uses similar technology and is usually cheaper than desalinating water, but has so far been too unpopular to be accepted by homes anywhere in the world except the Namibian capital Windhoek [Ref-45].

Alternative options are mainly experimental with no commercial operations in existence. Much research is focused on membrane technology having low thermal demands.

Liquid-liquid extraction (LLE) is currently used in various industrial applications. The main solvents used are amines and polymers but no solvent extraction desalination plants are currently commercially available. Amines have been rejected as potential solvents due to their presence in the final product. However, the 'Puraq' method is an LLE process that uses a specially tailored liquid polymer to extract salt out of seawater at temperatures around 29°C. This is in the experimental stage and no commercial applications are known to exist [Ref-44].

Another experimental technology relies on mass diffusion to evaporate salt water utilising waste heat [Ref-43]. Pumps spray salt water warmed as a by-product of power plant cooling processes into the top of a tower packed with a polyethylene matrix that creates a large surface area for the water to flow across as it falls. Fans at the bottom of the tower blow warm, dry air up the column. As the trickling salt water meets the warm dry air, it evaporates. Blowers push the now-saturated air into a condenser, the first stage in a process that forces the moisture to condense as freshwater. A small experimental prototype has been developed, producing about 500 gallons of freshwater daily. Calculations made by others are said to show that a larger version, tapping the waste coolant water from a typically sized 100 MW power plant, has the potential to produce 1.5 million US gallons daily. The cost is projected at $2.50 per thousand US gallons, compared with $10 per thousand US gallons for conventional distillation and $3 per thousand US gallons for reverse osmosis.

To be cost effective, the desalination equipment would have to extract as much heat as possible from the coolant water, so it would need to be incorporated into the NPP's design and would require a large area of land.

5.5.2.6 District Heating

District heating can be used to supply heating and hot water to a number of dwellings from a central heat source. This would require flow and return pipe work to be distributed to every dwelling to connect to a hydraulic heating interface unit typically requiring a flow temperature of 80 to 90°C at the point of use. Electrical energy will be required for circulation pumps to pump the water through the pipework. District heating permits the use of renewable heat technologies on a scale that would not be viable or practical on an individual scale.

The typical cost for installing a district heating scheme to serve 1,000 dwellings would be in the range of £4,000 to £8,500 per household [Ref-46]. The costs vary significantly depending on the ground conditions for installing the pipe work, the distances and the number of bends involved between the individual dwellings.

Larger schemes would benefit from further economies of scale resulting in lower maintenance costs and lower safety check costs when compared to the costs of installing and maintaining gas-fired central heating boilers to the individual dwellings. The whole life costs need to be lower than individual heating options for this to be financially attractive to residents.

To achieve the required water temperature at the point of use by raising the temperature of the condenser circulating water would have the impact of lowering electrical generation efficiency and reducing electrical output.

There is a body of thought in the UK [Ref-28][Ref-29][Ref-30] that is supportive of an alternative approach and on a larger scale than installing end of the pipe systems such as some of those discussed above. This concept is that of developing a heat network, taking waste heat from power stations such as coal fired, nuclear, energy from waste, Combined Cycle Gas Turbine (CCGT) and biomass power, etc., and distributing it over large distances to energy hubs in cities and towns incorporating district heating networks (DHN). The temperature of the media from the power plants would be raised at the expense of power generation but is returned at the same low temperature as if the heat was rejected without recovery. The concept of this process has been proven in Denmark [Ref-31][Ref-38].

A similar school of thought in the USA centres around the concept of 'Waste Heat Energy Parks' (WHEP).

The idea of co-locating a business near a power plant to use its waste heat or water is not new, but building dedicated systems to deliver hot water can be prohibitive with a single user. The concept of a WHEP is to combine multiple users who have different needs. Some would 'consume' the waste heat, whilst others would use the water after it is cooled, such as under floor greenhouse heating in winter with evaporative cooling in summer. Alternatively, the water may be passed through a spray aeration system (oriented spray cooling), oxygenating and cooling the water to a temperature suitable for use at an aquaculture facility.

Other businesses could be added to maximise the heat used and minimise the power plant's cost but maximum synergy among the users would be required to gain maximum benefit from the capital costs of the distribution system.

6. Groundwater

6.1 P&ID Requirements

The P&ID requirement relating to discharges to groundwater is reproduced below:

'If there will be discharges to groundwater, describe the nature and quantity of those discharges and provide an assessment of the impact on groundwater.'

6.2 Regulatory Context

Discharges to groundwater are controlled by the Environmental Permitting Regulations (England and Wales) Regulations 2016 (SI 2016 No.1154) (EPR 2016) [Ref-16], which make it an offence to cause or knowingly allow a groundwater activity to take place without an environmental permit or an exemption. Groundwater activities include the discharge of a pollutant which results in the direct or indirect input of the pollutant to groundwater.

6.3 UK ABWR Discharge to Groundwater

The UK ABWR generic design does not include any requirement for routine discharges to groundwater. There will not be any intentional discharges to groundwater at the generic UK ABWR site.

As a preventative measure, each building that contains radiation controlled areas has a roof drainage system. Rainwater is guided by the drainage system to a Seal Pit and then discharged to the environment with cooling water. Therefore no rainwater is discharged directly to groundwater.

The UK ABWR design will utilise BAT to prevent accidental leaks and spills of non-radioactive pollutants, which could give rise to accidental pollution of land and groundwater. These will include physical measures such as:

- Tank bunding (secondary containment) together with tertiary containment systems for potentially polluting substances.
- Hard surfacing areas of potential spill risk areas (e.g., loading areas, tanker bays, etc.).
- Use of oil interceptors on drainage systems.
- Provision of spill kits.
- A P&D system to collect and segregate potential leaked water (e.g. firewater water run-off).

In addition, occurrence of such events will be minimised through various measures such as:

- Staff training in spills prevention and emergency response.
- Emergency response exercises.
- Vehicle routing.
- Delivery and off-loading operational instructions.
- Inspection and preventative maintenance programmes for structures providing pollution prevention functions.

7. Operation of Installations (Combustion Plant and Incinerators)

7.1 Introduction

The purpose of this section of the report is to address the EA's P&ID requirements [Ref-1] with regard to the operation of combustion installations at the UK ABWR generic design. The information presented summarises the design information that is currently available. Whilst certain design details are not yet finalised (and will be developed further at the site-specific stage), the currently available design information is considered to be sufficient for the purposes of the GDA process in relation to the operation of installations.

7.2 P&ID Requirements

The EA has identified the information it requires to carry out the GDA in the P&ID [Ref-1]. The P&ID [Ref-1] requirement relating to operation of installations including combustion and incineration is reproduced below:

'Identify what combustion plant (for example, for standby generation or auxiliary boilers) will be provided:

- *If the aggregate rated thermal input of all combustion plant is greater than 50 MW, provide a comparison of the proposed technology against our sector guidance; and*
- *If the aggregate rated thermal input of all combustion plant is greater than 20 MW, describe how greenhouse gas emissions will be monitored.*

If the design includes an on-site incinerator with a capacity or 1 tonne or more per hour, provide a comparison of the proposed technology against our sector guidance.'

The proposed ABWR design does not include any requirement for on-site incineration (of either general hazardous / non-hazardous waste or radioactive waste) and it is assumed for the purposes of the GDA process that there will be no waste incineration activities at the generic UK ABWR site. The P&ID requirement to provide an assessment of proposed incineration technology against the EA's sector guidance is therefore not applicable and waste incineration is not considered further in this document.

This does not preclude a future UK ABWR operator from seeking to operate a waste incinerator at a UK ABWR site. However, compliance with the requirements of any relevant legislation in force at the time of application for the operation of the incinerator would be required.

The information to address the P&ID requirements is presented in six sections.

- **Regulatory context** (Section 7.3) - summarises the regulations relevant to combustion activities.
- **UK ABWR assumptions** (Section 7.4) - summarises the assumptions made in order to provide the basis for GDA.
- **UK ABWR combustion plant installation** (Section 7.5) - describes the combustion plant within the UK ABWR generic site.
- **Comparison with sector guidance** (Section 7.6) - the combustion plant specified as part of the UK ABWR generic design exceeds 50 MW_{Th} in aggregate; this section therefore identifies the EA's sector guidance against which it should be assessed and sets out the necessary comparison with that guidance.

- **Impact assessment** (Section 7.7) - describes the methodology for the assessments to be undertaken for GDA in order to identify the minimum recommended stack height to ensure adequate dispersion of emissions (D1 assessment), and to determine conservative ground level concentrations of the main combustion products (H1 assessment).
- **Greenhouse gas emissions monitoring** (Section 7.8) - describes the monitoring approach proposed to meet the requirements on greenhouse gas emissions monitoring. This is required as the aggregate rated thermal input of the combustion plant proposed for the generic site exceeds 20 MW_{Th}.

7.3 Regulatory Context - Combustion Activities

Combustion activities are controlled under the EPR 2016 [Ref-16].

Schedule 1, Part 2, Chapter 1, Section 1.1 of EPR 2016 identifies those combustion activities which come under the Regulations. This listing includes the following relevant activity:

1.1 Part A (1) (a) Burning any fuel in an appliance with a rated thermal input of 50 or more megawatts.

The interpretation provided in the subsequent paragraph of Section 1.1 states:

For the purpose of Part A (1) (a) of this Section, where 2 or more appliances with an aggregate rated thermal input of 50 megawatts or more are operated on the same site by the same operator those appliances must be treated as a single appliance with a rated thermal input of 50 megawatts or more.

It will therefore be necessary for the site operator of a UK ABWR to apply for an Environmental Permit for the operation of the combustion activity at the site-specific permit application stage, since the aggregate rated thermal input of the auxiliary boilers and emergency diesel generators proposed is greater than 50 MW_{Th} (see Section 7.4 below).

The permit for the combustion activity may be combined with the water discharge Environmental Permit.

7.4 UK ABWR Assumptions

The following assumptions have been made in order to provide the basis for the development of Hitachi-GE's approach to addressing the GDA requirements relating to the operation of combustion installations (covered by non- Radioactive Substances Regulations (RSR)) within the generic nuclear site:

- The ABWR design does not include any requirement for on-site incineration of either general waste (hazardous or non-hazardous) or radioactive waste. Hitachi-GE has therefore assumed that there will be no waste incineration installation at the generic UK ABWR site.
- Combustion plant at the generic site consists of the following main plant items:
    - Three (3) standby Emergency Diesel Generators (EDGs), each with a rated thermal input of 18.0 MW_{Th} and an output of 7.2 MW_e; these are to be located individually in separate EDG buildings adjacent to the R/B.
    - Two (2) standby diesel driven Backup Building Generators (BBGs), each with a rated thermal input of 6.14 MW_{Th} and an output of 2.4 MW_e, located in the back-up building.
    - One (1) Diverse Additional Generator (DAG) with a rated thermal input of 18.0 MW_{Th} and an output of 7.2 MW_e; the purpose of the DAG is to provide backup to a common cause failure of the EDGs and it has therefore been assumed for GDA that this unit will be similar to the EDGs themselves; however, the ultimate size, drive system, fuel type and location of the DAG is still under design.

- Two (2) fire protection pumps, each with a rated thermal input of <3 MW_{Th}; the fire protection pumps are located together in a single building and are considered as trivial for the purposes of assessing the combustion activity for GDA (see below).
- Two (2) auxiliary diesel-fired boilers, each with a rated thermal input of 24.1 MW_{Th}, located in the House Boiler Building (HB/B). Diesel-fired boilers have been assessed at generic stage as they represent a worst case in terms of emissions to air, and the requirement for the storage on-site of hazardous chemicals (diesel). The option to use electrically powered boilers instead of diesel fired boilers will be reviewed at the site-specific stage.

- The aggregate rated thermal input of relevant combustion capacity is therefore 132.48 MWTh.
- All principal combustion plant as described above will be fired on diesel, assumed to be standard UK specification Ultra-Low Sulphur Diesel (ULSD). A possible exception to this is the DAG, which could be a gas fired unit; however this will be determined at the site-specific stage.
- Each generator will exhaust to air via an appropriate silencer and individual stack which will exit the building through the roof with the final emission point orientated vertically.
- The auxiliary boilers will exhaust to air via a single combined flue which will exit the building through the roof with the final emission point orientated vertically.
- The diesel generator systems will include appropriate frost protection systems, where necessary.
- The equipment will have suitable industry standard electrical switchgear and transmission systems for the injection of generated power into the wider UK ABWR site electrical system.
- The auxiliary boilers will be equipped with the following:
  - Appropriate boiler feed-water systems with purified water generation for maintenance of boiler water quality;
  - Suitable steam condensate recovery systems in order to minimise purified water usage, with condensate returned to the boiler feed water tank.
- The combustion installation will be provided with bulk diesel storage tanks equipped with appropriate containment systems and pollution prevention measures; each combustion unit will have a suitable day tank which will be supplied from bulk storage via dedicated above ground pipework systems.
- The combustion installation will include appropriate facilities for the storage of other raw materials (for example glycol, maintenance sundries, etc.).
- There will be bulk tank storage for lube oil equipped with appropriate pollution prevention measures together with suitable facilities for diesel generator lube oil changes.
- The combustion installation will include appropriate facilities for the storage of generated wastes, including storage for spent fuel oil and waste lube oil.
- Abatement systems for combustion gases will be considered where appropriate, subject to technical and economic feasibility, and in accordance with the demonstration of BAT.
- Emergency diesel firewater pumps and other minor local combustion plant (e.g., isolated space-heating boilers) are likely to have individual rated thermal inputs of less than 3 MW_{Th} and may be considered as minor plant. It has therefore been agreed with the EA (meeting 29th January 2015) that they may be excluded from the impact assessment undertaken (Section 7.7). Such units are not considered further in this GDA.
- The purpose of the DAG as backup to the EDGs means that it would not operate in an emergency scenario at the same time as the EDGs. Emissions from the DAG will therefore not add to the

assumed worst case scenario of all EDGs and the BBG operating together in an emergency scenario. The DAG is of a similar capacity to one of the EDGs and any impact caused by the DAG when it operates will be similar to a single EDG during maintenance and commissioning activities. It has therefore been agreed with the EA (29th January 2015) that excluding the DAG from the short term impact assessment of the combustion installation will not affect the validity of the assessed potential worst case impact.

- The GDA submission will not require a Site Condition Report, since this is a site-specific document. Such a report will be prepared in conjunction with the application for permitting of the combustion installation prior to commencement of operations.

Note that the assumptions described above are those made for the GDA assessment of the UK ABWR. The Combustion Installation requirements will be reviewed at the site-specific stage, and may be changed from those described above, depending on the specific requirements of the site, and the strategy to be taken for the type of combustion plant used. For the purposes of assessing the potential impacts the assumptions made in this GDA assessment represent the worst case.

7.5 UK ABWR Combustion Plant Installation

The scope of the combustion installation within the generic UK ABWR site will be defined in order to facilitate delivery of the following requirements of the GDA process:

- Definition of the boundary of the permitted installation.
- Assessment of likely stack heights for effective dispersion and dispersion of combustion gases, using D1 where appropriate.
- Screening level dispersion modelling of combustion gases (using the EA's H1 Environmental Risk Assessment Screening Tool, and further screening where appropriate) in order to assess the potential for environmental impact.

In summary, the UK ABWR combustion installation for the generic site will include the following plant:

- Three (3) standby EDGs, each with a rated thermal input of 18.0 MW_{Th}, located individually in separate EDG buildings adjacent to the reactor building.
- Two (2) standby diesel driven BBGs, each with a rated thermal input of 6.14 MW_{Th}, located in the back-up building.
- One (1) DAG with a rated thermal input of 18.0 MW_{Th}, location to be confirmed.
- Two (2) auxiliary diesel-fired boilers, each with a rated thermal input of 24.1 MW_{Th}, located in the HB/B.

The final selection of appropriate plant for the UK ABWR combustion installation at the site-specific stage will be based on a review of suitable combustion plant and associated equipment available in Europe, with each selection determined in accordance with an assessment of BAT.

7.5.1 Operation of the Combustion Plant

This section is intended to describe the purpose of each item of the combustion plant and when it would be used.

7.5.1.1 Emergency Diesel Generators (EDGs)

The three EDGs are required to supply emergency electrical power to safety rated equipment to allow safe shut-down of the reactor in the event of a Loss of Off-site Power (LOOP), or a Loss of Coolant Accident (LOCA) simultaneously with a LOOP. The EDGs are therefore required to start up automatically and rapidly on receipt of a start-up signal in the event of a LOOP or LOCA.

7.5.1.2 Diesel driven Backup Building generators

The two diesel driven BBGs supply emergency electrical power to back-up safety-related systems such as the Flooding System of Specific Safety Facility (FLSS) or the Standby Liquid Control System (SLC), where power is essential to drive supply water pumping systems. These systems also support the delivery of a secondary means of providing for the loss of cooling function.

If required, the BBGs will therefore operate in parallel with the EDGs and will be required to start up automatically and rapidly on receipt of a start-up signal.

7.5.1.3 Diverse Additional Generator

The purpose of the single DAG is to provide backup to a common cause failure of the EDGs and provide power for essential safety systems. This unit will be started manually when required as a result of failure of the EDGs and will not operate in parallel with the EDGs.

7.5.1.4 Generator Operating Scenarios

It is anticipated that there will be three operating scenarios for the EDGs and BBGs[11]:

- Commissioning.
- Routine Testing.
- LOOP.

It is likely that each generator unit (EDGs and BBGs) will be commissioned singly and separately with minimal circumstances of multiple running. A commissioning programme of around 10 - 14 days is expected to be required. A single commissioning test for each generator unit is expected to last for a duration of 5 hours 40 minutes (from start to stop).

Routing testing is expected to be conducted on one EDG or BBG at a time. Under normal circumstances no generators will operate, other than for routine testing.

The test programme is anticipated to comprise the following surveillance and regular tests. Generators are operated individually in the tests:

- Regular test: every 18 months for three hours (from start until completion). Time at maximum continuous rating (MCR) will therefore be <3 hours:
- Surveillance test: monthly for one hour (from start until completion). Time at MCR therefore <1 hour. Surveillance test is not undertaken in the month when the regular test takes place.

If more than three failures were to be recorded on the monthly testing for a particular generator, then that generator would be placed onto a weekly test routine until at least four satisfactory sequential test results had been achieved.

The conservative worst case test programme in any one year would therefore be for all EDGs and BBGs to have their 18 month tests combined with all EDGs and BBGs having their monthly tests (minus the one month when the surveillance test is replaced by the regular test). Routine testing will not involve simultaneous operation of multiple EDGs or BBGs.

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[11] For the purposes of this GDA, the commissioning and testing programme for the DAG is assumed to be the same as for the EDGs and BBGs.

LOOP (and LOCA caused by LOOP) incidents can vary between short events (lasting minutes to several hours) and long events (lasting from days to over a week). The probability of occurrence is reviewed in [Ref-49].

In the event of a LOOP, it is assumed that the likely scenario is that all EDGs and BBGs will start-up automatically. The EDGs and BBGs may then continue to operate until either off-site power is restored, or the ABWR is safely shut down. Whilst EDG power will continue to be required for residual cooling and other safety-related functions, they may be progressively shut down as demand falls off. For both short and extended LOOP events, it is anticipated that all generators will operate at MCR continuously whilst they remain on line, until demand begins to fall off, when output from individual units may be gradually reduced prior to shut down.

The DAG will only operate during either short or extended LOOP events if there is a failure of one or more of the EDGs. The unit will be started manually according to need. Whilst it is possible for the EDG and DAG to operate at the same time, this is not expected to occur or to be required. The DAG may operate at the same time as the BBGs. The maximum operating scenario under LOOP circumstances is therefore three EDGs and two BBGs.

7.5.1.5 Auxiliary Boilers

The two auxiliary boilers provide steam to the site during start-up, normal operation and shut-down. Steam uses include process users, a frost protection demand (which may not be as significant under UK conditions) and supply to building HVAC systems.

It is expected that the need for steam to provide frost protection for the UK ABWR will be reviewed at the site-specific stage.

7.5.1.6 Auxiliary Boiler Operating Scenarios

It is envisaged that there will be three operating scenarios for the auxiliary boilers:

- Commissioning.
- Start-up/shut-down load.
- Routine Operation.

It is assumed that both boilers will be commissioned simultaneously, and will operate at full load during the commissioning programme for up to five days. This is a one-off activity which will not reoccur. During start-up or shut down, the auxiliary boilers will deliver the steam demand normally supplied from other station steam systems. The longest duration steam demand in start-up mode is the turbine gland seal, which is required for 17 hours.

For routine operations, it is expected that during the winter, both boilers will be required to operate at up to full load whereas for summer loading, one boiler operating at 50% nominal will suffice. At least one boiler will therefore be operational during most circumstances.

7.6 Comparison with Sector Guidance Note

Having established that the combustion plant to be provided at the generic UK ABWR consists of emergency standby diesel generation units and auxiliary diesel-fired boilers with an aggregate rated thermal input greater than 50 MW_{Th}, the EA's P&ID [Ref-1] for the GDA requires a comparison of the proposed technology against relevant guidance.

In this instance, the appropriate guidance has been identified as follows:

- General guidance for industrial activities provided in How to comply with your environmental permit (HCEP) [Ref-50].

- The Combustion Sector Guidance Note (CSG) [Ref-51].
- For the purposes of a screening level impact assessment of emissions arising from operation of the generic UK ABWR site, the EA's H1 Guidance Note and its annexes (e.g., Annex F Emissions to Air) have been referenced (H1) [Ref-52][Ref-53][Ref-54].
- For the consideration of energy efficiency, the EA's Horizontal Guidance Note IPPC H2 Energy Efficiency has been referenced (H2) [Ref-55].

For the purposes of the comparison with EA guidance, the installation has been assumed to be as defined above in Section 7.5.

The required comparison of the design and operation of the combustion plant proposed for the generic UK ABWR against the indicative requirements identified in the Sector Guidance Note (and, by extension HCEP and other relevant guidance) is provided in the following sections, covering:

- Appropriate measures.
- Permitted activities.
- Energy efficiency and efficient use of raw materials and water.
- Avoidance, handling, recovery or disposal of wastes.
- Point-source emissions to water – including controls on surface water drainage systems from fuel and raw material storage areas and handling and treatment of process effluents including de-ionization effluent, boiler water blow-down and cleaning water.
- Point-source emissions to air – including in-process controls and consideration of abatement technologies for oxides of nitrogen (NO_x), oxides of sulphur (SO_x), carbon monoxide (CO), volatile organic compounds (VOC) and particulate matter. HCEP requires operators to assess the dispersion capability of their vent and chimney heights and make an assessment of the fate of the substances emitted to the environment – this is discussed in the impact assessment section (Section 7.7).
- Fugitive emissions – control of fugitive emissions to air, water, groundwater and ground.
- Monitoring – this includes monitoring requirements and a requirement to meet the indicative benchmark standards for emissions except in justifiable circumstances.
- General management, including having a written management system, responsible persons, training and records.
- Site security.
- Control of odour, noise and vibration.
- Emission benchmarks.
- IED.

7.6.1 Appropriate Measures (HCEP)

Reasonable and appropriate measures will be deployed in order to prevent or minimise the potential for pollution which may arise as a consequence of the operation of the combustion installation. These measures will be based on those described in HCEP, industry sector guidance, relevant horizontal guidance and accepted good practice, in conjunction with an assessment of costs and benefits.

Where alternate measures not described in guidance are used, these will be explained with an appropriate level of detail, and a justification will be provided which demonstrates that such measures deliver an equivalent level of protection to those indicative measures described in guidance.

Where appropriate for specific circumstances, such as the control of odour or noise emissions, a management plan may be developed and agreed with the EA at site permitting stage.

7.6.2 Permitted Activities (HCEP)

The only activities proposed for operation under the EPR 2016 [Ref-16], will be those described as being within the scope of the combustion installation within the generic UK ABWR (see Section 7.5).

7.6.3 Energy Efficiency (HCEP, CSG & H2)

This section has been prepared having regard for the EA's H2 Guidance Note [Ref-55] in addition to HCEP and the CSG.

It is expected that a written and published energy policy will be prepared by the site operator which demonstrates the commitment of senior management to energy efficiency. The policy will include targets and performance indicators which will be integrated with the overall aims, policies and corporate management systems of the wider UK ABWR site. The policy will provide the framework for a coherent and sustained approach to energy efficiency. It will ensure that proper consideration is given to proposed energy efficiency projects and that appropriate importance is assigned to energy efficiency at all levels of the organisation.

In order to ensure continuous improvement in energy efficiency, it is anticipated that systems or procedures will be in place for the continuous measurement and assessment of energy consumption within the installation. The primary function of such a system will be to support the overall energy policy by enabling the collection, analysis and reporting of data relating to energy performance as well as facilitating the setting, review and revision of energy performance targets. These activities are often referred to as monitoring and targeting (M&T).

The starting point for M&T is typically the measurement of energy consumption within the installation but in broader terms, it is fundamental to good energy management, playing a key role in the following:

- Identifying areas of energy wastage.
- Highlighting exceptions to normal performance.
- Evaluating the impact of energy saving actions or of faults in equipment and its operation.
- Setting realistic targets for improvement.

7.6.3.1 Basic Energy Requirements (1)

The purpose of the standby generators is to generate electricity in order to provide power for UK ABWR safety systems in the event of the unavailability of normal grid-fed power supplies.

The primary purpose of the auxiliary boilers is to generate and export steam to the UK ABWR site steam network in order to provide steam for essential systems. The auxiliary boilers therefore have a duty under normal routine operations as well as emergency circumstances.

The over-riding requirement for the combustion installation is the safety of the UK ABWR site. Whilst nuclear safety must remain paramount, and operation of the combustion units will be infrequent and short term, the energy efficiency of the selected combustion units will receive appropriate consideration.

7.6.3.1.1 Energy Consumption

No definitive energy consumption data are available for the generic UK ABWR combustion installation at this stage of the design process, since final equipment selection has not been undertaken. Analysis of energy consumption is therefore only possible to a limited degree and further assessment will be conducted once the specific plant and equipment to be used has been identified.

The required electrical output capacity of the proposed emergency and back-up generators has been estimated by reference to the generic UK ABWR design and will be further refined during the detailed design process.

Likewise, the steam generation capacity of the auxiliary boilers has also been estimated by reference to the generic UK ABWR design and will be further refined during the detailed design process.

7.6.3.1.2 Specific Energy Generation

For the purposes of this review, specific energy generation has been defined as kWh of energy (electricity) generated per kilogram of diesel consumed by the generator set. Since the engines will normally operate at peak efficiency and maximum output, the predicted specific energy generation for the installation is expected to be in line with the efficiency of the nominal engine selection based on the UK ABWR generic design, as set out in Sections 7.4 and 7.5 above.

For the EDGs and the DAG, fuel consumption is specified as 1490 kg/h diesel. For 7.2 MW_e output, specific energy generation is therefore 4.832 kWh/kg diesel. Similarly, for the BBGs, where fuel consumption is specified as 520 kg/h and output is 2.4 MW_e, specific energy generation is 4.615 kWh/kg diesel.

The nominal engine selections are expected to deliver an electrical efficiency of around 40% or 0.4 MW_e/MW_{Th} rated thermal input for all units (EDGs, BBGs and DAG), which is in line with typical performance for large diesel generator sets of this type. It is expected that this will be the minimum performance of the selected units. At the procurement stage of the project, a thorough assessment of available diesel generator sets suitable for the proposed duty will be conducted with a view to the selection of units with optimum energy efficiency and performance. Specific engine efficiency techniques such as turbo charging with air intercooling will be considered, having regard for the potential for increased NO_x emissions per generated kWh.

In the absence of a definitive generator set selection at this stage of the design process, it is not considered necessary or appropriate to conduct a performance benchmarking exercise of the nominal generator selections against available data for diesel generator units. However, it is widely considered that diesel prime mover generator units are the most efficient and reliable option for this type of emergency, short term operational scenario. The selection of diesel as the fuel offers security of supply for emergency circumstances which is much less likely to be disrupted than, for example, natural gas supplied from the Grid. Diesel generator units are therefore considered to be BAT for the operational and emergency requirements of the UK ABWR site.

For similar reasons, diesel fired auxiliary boilers are considered to be BAT for the supply of steam under both normal routine and emergency scenarios, based on the paramount requirement for nuclear site safety. The units are expected to be industry standard package type fire tube boilers with low-NO_x burners and a thermal efficiency of around 90%.

7.6.3.2 Basic Energy Requirements (2)

7.6.3.2.1 Operating and Maintenance Procedures

All plant and equipment in the combustion installation will be subject to planned preventative maintenance under a scheduled programme which will have regard for manufacturer's recommendations. This will ensure that all combustion units are maintained to an appropriate standard to maximise operational efficiency.

The auxiliary boilers and associated steam distribution and steam condensate systems will be maintained so as to minimise the occurrence of leaks, which may reduce overall energy efficiency.

Key parameters of the diesel prime movers and boilers will be monitored in order to assess operational performance and ensure optimum efficiency. Recorded data will be regularly reviewed so that performance trends may be identified and addressed.

Since the diesel generator sets are for emergency power generation purposes, optimised warm-up for improved fuel efficiency may not be considered. Under emergency circumstances, the units will be expected to start immediately and achieve maximum output in very short timescales and initial (start-up) fuel efficiency cannot be considered as a key operating parameter. Once the engines have reached normal operating temperature (usually within approximately 15 - 20 minutes of start-up), peak efficiency will be achieved.

At least one auxiliary boiler will be operating at all times under normal circumstances. Since the requirement for rapid emergency start-up does not apply, the units may be managed so as to deliver optimised efficiency across the operating range, noting that boiler start-up must be undertaken within the restrictions which typically apply in order to minimise the risk of damage to the unit arising from thermal expansion.

7.6.3.2.2 Basic Physical Measures

The design and installation of steam trap and steam condensate return systems will be optimised for energy recovery via condensate return to the boiler feed water tank. Boiler heat transfer surfaces which might be prone to fouling will be cleaned regularly, at an appropriate frequency, in order to maintain heat transfer efficiency.

Gross inefficiencies will be avoided by the application of appropriate insulation and incorporation of measures which avoid the unnecessary discharge of steam, hot water or condensate.

7.6.3.2.3 Building Services

The energy efficiency of services in buildings that are included within the permitted activities, for example process buildings, control rooms, etc., will be optimised when building designs are completed. This includes energy-consuming services such as space heating and cooling, hot water, ventilation and lighting, where low-cost measures can save up to half of the buildings-related energy use. The assessment of appropriate energy efficiency techniques will have due regard for implications relating to health and safety at work, for example, in relation to the provision of adequate lighting.

7.6.3.2.4 Energy Efficiency Plan

It is expected that an energy efficiency plan will be developed for the UK ABWR combustion installation that identifies and appraises energy efficiency techniques applicable to the activities. This will include:

- The identification of all techniques described in relevant guidance that are applicable to the installation but that have not yet been implemented, including basic energy requirements and further energy efficiency techniques.
- An estimate of the annual carbon dioxide savings of each technique.
- The identification of any techniques which may lead to adverse environmental impacts.

The objective of the energy efficiency plan will be to provide the basis for an ongoing energy efficiency improvement programme to demonstrate that basic good energy management principles are in place and that the key energy saving opportunities for the installation have been identified and appraised in terms of their costs and benefits. This will enable the scoping and prioritisation of improvement measures for implementation.

7.6.3.3 Further Energy Efficiency Techniques

It is widely accepted that the most effective energy efficiency measures can usually be incorporated at the design stage for new installations, particularly with regard to the specification for procurement of equipment and buildings. At this stage, integrated energy efficiency techniques such as heat recovery, water minimisation and heat and power demand can be optimised by consideration of energy consumption and recovery opportunities for the installation as a whole. There are also components and control systems of larger equipment or process plant which can be optimised to improve energy efficiency at the design / procurement stage.

The development of additional energy management techniques will be considered during the commissioning and initial operation of the combustion installation and an energy management programme will be devised in conjunction with energy management planning for the wider UK ABWR site.

7.6.3.3.1 Motors and Drives

Motive power can be a significant element of energy consumption in industrial processes. The capital cost of a higher efficiency motor is usually no more than a standard motor but the efficiency gain of 2 -3% can deliver significant savings over the lifetime of the motor. In addition, use of variable speed drives (VSDs) to modulate the load on fans and pumps is a much more energy-efficient method of regulating flow than throttles, dampers or recirculation systems. Such techniques will be considered during the design and identification of the specific plant to be used, in particular, for boiler combustion air fans and boiler feed water pumps, where VSDs may deliver significant energy savings.

7.6.3.3.2 Heat Recovery

Significant savings may be achieved through the recovery of waste heat. For reciprocating engines, such as the emergency and back-up diesel generators proposed for the UK ABWR, it is often technically and economically feasible to recover heat from exhaust gases, cooling systems, lube oil coolers and turbo intercoolers. Higher grade heat recovered in this manner may be used for process heating whilst the lower grade heat can supplement building heating or low grade process heating requirements.

However, owing to the intermittent and short term nature of the emergency power generation duty of the combustion installation at the UK ABWR, Hitachi-GE considers that recovery of heat from the engines for operation as a CHP is not technically or economically feasible. Furthermore, the design of the UK ABWR does not include suitable customers within the wider ABWR site for the intermittent and short term supply of relatively low grade heat.

In line with industry standard techniques for standby generation sets, it has therefore been concluded that heat recovery in order to achieve CHP operation of the EDGs, BBGs and DAG at the generic UK ABWR combustion installation is not BAT.

7.6.3.3.3 Water Minimisation

Use of closed loop cooling water systems to minimise water treatment requirements (and associated energy usage) will be implemented for the emergency and back-up diesel generators at the UK ABWR.

The design and installation of steam trap and steam condensate return systems will be optimised for the recovery of steam condensate to the boiler feed water treatment system in order to minimise the demand for freshwater.

7.6.3.3.4 Low Energy Technology

Specialised low energy technology is not appropriate for consideration in relation to the UK ABWR.

However, industry standard diesel generators and boilers will be identified for optimum energy efficiency performance, having regard for the over-riding nuclear safety requirement for reliable emergency power and heat generation systems.

7.6.3.3.5 Optimised Design and Layout

Where practicable, reduced piping runs and other measures to minimise pressure losses will be selected.

7.6.3.3.6 Process Control and Instrumentation

The application of appropriate control and instrumentation for optimum operational conditions and energy efficiency will be addressed later in the detailed design stage, when further information on specific plant and equipment to be used is available.

7.6.3.3.7 Energy Supply Techniques

Owing to the over-riding nuclear safety characteristic of the duty specified for the UK ABWR combustion installation, alternative options for the supply of power and heat under emergency circumstances are relatively limited. Whilst other techniques may be reviewed later in the detailed design stage, it is widely considered that diesel prime mover generator units are the most efficient and dependable option for this type of emergency, short term operational scenario and that they are likely to be BAT for these circumstances.

7.6.4 Efficient Use of Raw Materials and Water (HCEP)

The principal raw materials used within the combustion installation at the UK ABWR will be diesel, water and lubrication (lube) oil. Other materials to be used will include general maintenance consumables and anti-freeze (glycol) for the engine cooling systems.

It is expected that the diesel used as fuel for the emergency and back-up generators and the auxiliary boilers will be UK standard specification ULSD in order to minimise emissions of sulphur dioxide (SO_2) from the combustion units. The quantity of diesel used will be minimised by the inherent energy efficiency of the selected combustion units, which will be a key criterion for their selection at the procurement stage of the project.

Assuming 14 h/y operation for each of the emergency and back-up generators, estimated annual diesel usage for the routine testing programme is approximately 98 tonnes (excluding replacement of spent diesel from storage).

For routine operation of the auxiliary boilers, it is expected that during the winter, both boilers will be required to operate at up to full load whereas for summer loading, one boiler operating at 50% MCR will normally suffice. If it is assumed that, on average across a typical year, this is equivalent to one boiler operating at MCR continuously, approximate fuel consumption by the auxiliary boilers may be estimated as 22,776 tonnes.

Alternative fuels have been considered but the over-riding requirement for nuclear safety dictates that the fuel must offer security of supply for emergency circumstances. The selection of diesel as the fuel allows the bulk storage of an appropriate minimum quantity for the expected emergency usage on site. Whilst such a storage facility requires on-site holding of the fuel supply in liquid form (with the associated pollution risk), it is less likely to be disrupted than, for example, natural gas supplied from the Grid where there is no on-site holding. Storage of a liquid fuel on site in an appropriate manner allows the site to function in isolation from dependency on Grid based supplies in the event of an emergency. It is therefore considered that the selection of diesel as the fuel for the combustion installation is BAT for the primary duty.

The lube oil used for the diesel generator engines is anticipated to be a specific mineral oil which is recommended for the duty by the engine manufacturer. The consideration of alternative materials for the duty is likely to be inherently restricted by the manufacturer's warranty limitations for the engines. Regular oil changes will be required under the planned preventative maintenance regime for the engines in order to maintain peak operating efficiency and minimum emissions performance. However, oil changes, and hence the overall quantity used, may be minimised by regular sampling and analysis of the lube oil for signs of deterioration or accumulation of combustion contaminants and metal from normal engine wear. The results of such analysis may be used to determine the optimum oil change frequency.

Lube oil and waste lube oil removed from the diesel engines will be stored in dedicated double-skinned bulk storage tanks equipped with appropriate containment measures for the prevention of pollution by fugitive loss or spillage. Waste lube oil will be dispatched from site to a suitably licensed waste oil recovery operator where it will be recovered for re-use or recycled as a secondary fuel.

The final specification of the generator sets has not been confirmed for the GDA process. In the absence of definitive data, it is estimated that annual lube oil usage is likely to be approximately 5,000 litres. The actual volume will depend on the lube oil management regime adopted, which will be determined in accordance with the operating pattern of the engines and the manufacturer's recommendation for oil change frequency for generators on standby duty with low operating hours.

Water is used in the generator set engine cooling systems, mixed with anti-freeze (usually glycol based) for the protection of the engine during winter conditions. Other water treatment chemicals, such as biocides, may be included to prevent algal or other biological growth within the cooling system, which may lead to fouling and inhibition of heat transfer. Typically, the closed loop cooling system is charged with water / glycol during engine installation and then simply topped up periodically with water, glycol and treatment chemicals as indicated by routine planned maintenance inspections. This technique inherently minimises water and chemical usage in the engine cooling system.

In a similar way, it is expected that boiler feed water will be prepared from fresh (mains) water. Boiler feed water treatment chemicals typically include an oxygen scavenger, a corrosion preventer and biocides to prevent algal or other biological growth within the system which might inhibit heat transfer by fouling. Design of the steam condensate recovery and return system during the later stages of the project will minimise freshwater usage by maximising the return of steam condensate to the boiler feed water system.

The use of proprietary boiler feed water treatment packages is relatively standard across a wide range of industries and their chemical properties and potential for environmental harm are widely known.

The usage of general maintenance consumables, including glycol, is not expected be substantial, nor is it anticipated that the use of such materials in relatively small quantities is likely to present significant potential for environmental harm. Alternative materials will be considered, according to the duty, at the procurement stage and at periodic intervals thereafter.

The storage and handling of these materials is discussed in the following sections.

7.6.5 Avoidance, Recovery and Disposal of Wastes (HCEP & CSG)

The principal waste streams to be expected from the UK ABWR combustion installation are spent diesel and waste lube oil.

Diesel fuel stored for long periods has the potential to deteriorate and become 'spent', sometimes owing to algal growth in the fuel, which may occur in the presence of water. In such circumstances, the diesel can be treated to reinstate it to useable condition, essentially by cleaning it. This is either done by a contractor attending site with specialist equipment or by shipping the spent diesel off-site to a specialist contractor for treatment and return. Under normal circumstances, it is therefore returned to use but may be considered waste once the need for treatment has been identified until it is returned as reinstated fuel.

Measures can be adopted which minimise the risk of diesel deteriorating in this manner (and thereby minimise the generation of waste), for example, by ensuring that water is excluded from bulk storage and all diesel deliveries. Careful stock management and stock cycling will also reduce the potential for fuel deterioration by ensuring that fuel is dispensed on a first-in, first-out basis. Such measures will be considered and implemented as appropriate at the procurement stage of the project.

Waste lube oil is generated as a consequence of lube oil changes from the diesel generator sets. Minimisation of this waste stream is achieved by regular sampling and analysis of the lube oil for signs of deterioration or accumulation of combustion contaminants and metal from normal engine wear. The results of such analysis may be used to determine the optimum oil change frequency, so that lube oil is only changed out when it is essential.

It is only possible to estimate an approximate figure for annual waste lube oil generation for the GDA process, since the final selection of the generator sets will not be undertaken until later in the detailed design stage. However, as noted above in Section 7.6.4, it is expected that approximately 5,000 litres of waste lube oil will be produced.

In general, waste avoidance or reduction measures will be implemented throughout the operation of the combustion installation at the UK ABWR. Where waste is produced, recycling and recovery options will be investigated and waste disposal will only be selected in the absence of a technically and economically feasible recovery or recycling option. All waste streams will be comprehensively characterised and quantified prior to disposition.

7.6.6 Point Source Emissions to Water (HCEP & CSG)

It is not expected that there will be direct emissions to water from the combustion installation at the UK ABWR. For the purposes of the GDA process, it is assumed that all aqueous emissions from process sources (including cooling water system blowdown and boiler blowdown) and surface water run-off (including firefighting water and storm water) will be directed to drainage and effluent systems within the wider UK ABWR site. These drainage systems, associated effluent treatment and subsequent discharges to water are described in Section 5.

There will be measures implemented within the combustion installation for the containment and control of sources of polluting material which have the potential to cause harm to the aquatic environment. These measures will be intended to prevent releases of polluting material and are described further below, to the extent that current design information allows for GDA.

7.6.6.1 Diesel Storage

The design of the diesel storage facilities has yet to be finalised. However, to meet the Nuclear Safety Case requirement for the site, the emergency diesel generators are required to have seven days' supply of fuel. Therefore, for the purposes of the GDA process, it has been assumed that sufficient diesel will be stored within the generic site to provide seven days' supply for all the emergency and back-up diesel generators (EDG, BBG and DAG).

Assuming a similar basis for the storage of fuel for the two auxiliary boilers (i.e., seven days' supply), then the total bulk diesel requirement for the UK ABWR will be 2,863 m^3.

Whilst the detailed configuration of the bulk storage facilities has not yet been finalised, it is anticipated that the EDGs, BBGs and DAG will each have dedicated tankage for the storage of diesel allocated to their operation. In addition, each generator will be equipped with a suitably sized day tank which will allow up to 12 hours of operation before it requires topping up.

Likewise, the auxiliary boilers will have dedicated bulk storage. However, since the boilers are to operate with at least one unit continuously online, it is unlikely that they will be equipped with day tanks.

All diesel storage tanks will be compliant with the EA's Pollution Prevention Guide (PPG) 2, Oil Storage [Ref-56] and the Control of Pollution (Oil Storage) (England) Regulations 1999 (PPG2) [Ref-57], as appropriate.

In particular, all tanks will be situated within impervious secondary containment systems (bunds) which provide a capacity of at least 110% of the nominal capacity of the largest tank or 25% of the aggregate nominal capacity of all tanks within the containment system, whichever is the larger.

All diesel storage, handling and containment systems will be included in the planned preventative maintenance system for regular inspection and maintenance for the assurance of containment integrity.

Purpose-designed tanker handling areas with containment systems and dedicated blind sumps will facilitate bulk deliveries of diesel (and collection of spent diesel by licensed contractor for treatment at an appropriately permitted facility, if necessary). All deliveries and collections will be by road tanker. All tanker handling activities and transfers will be directly supervised and subject to procedural controls and systems, with particular attention paid to the handling of flexible transfer hoses and the containment and collection of minor spillages. Spill kits and other emergency spillage response measures will be provided at appropriate locations. All operatives involved in the handling and transfer of diesel will be suitably trained and their competence regularly assessed.

As the preliminary design currently stands, the Backup Building (B/B) bulk diesel tanks and the HB/B bulk diesel tanks will be located above ground, along with all associated pipework and diesel delivery systems.

However, it is currently proposed that the bulk diesel tanks associated with the EDGs and DAG will be situated in the basements of the buildings housing the EDGs and DAG. The basements will be below ground level. Appropriate leak detection systems[12] will be in place for both the tanks and associated pipework. Details of these will be finalised at the site-specific stage.

Whilst this design proposal may be revised at the site-specific detailed design stage, it is considered that both above ground and below ground storage systems may be engineered to deliver BAT, under most circumstances. It is noted that nuclear safety requirements, or restrictions on available above ground land area for a UK ABWR site, may dictate that it is necessary to locate the EDG and DAG diesel tanks below ground. However, it is also recognised that below ground tanks present a greater risk to the environment and that the requirements of the Groundwater Regulations [Ref-58], will need to be considered if this design proposal is taken forwards at the site-specific stage. In addition, it will be necessary to have regard for the EA's Groundwater Protection: Policy and practice (GP3) [Ref-59] and the Department for Environment, Food and Rural Affairs' (DEFRA's) Groundwater Protection Code for petrol stations and other fuel dispensing facilities involving underground storage tanks [Ref-60]. In particular, a detailed assessment of environmental risk arising from the underground storage of diesel is likely to be required and appropriate measures for containment incorporated into the detail design. Such issues will be considered further at the site-specific detailed design phase.

In addition to secondary containment, appropriate consideration of the capacity, design and operation of tertiary containment systems will be addressed at the site-specific design stage.

7.6.6.2 Lubrication Oil Storage

Lube oil for the emergency and back-up generator engines will be stored in dedicated, double-skinned, above ground tanks, with permanent, above ground pipework for the distribution of lube oil to each engine. Likewise, dedicated, double-skinned, above ground tanks will be used for the storage of waste lube oil removed from the engines during oil changes. Waste lube oil will also be transferred via permanent above ground pipework.

[12] Compliant with standard BS EN 13160-1-2003 which specifies the general principles for leak detection systems for use with double-skin tanks, single-skin tanks and pipework designed for water polluting fluids.

All lube oil tanks will be situated on hardstanding and may be located inside buildings in association with a particular emergency or back-up generator set. Where appropriate, suitable crash barrier protection of the tank for the prevention of vehicle impacts will be provided.

Since the tanks will be double skinned and suitably protected from vehicle impact, further secondary containment systems (such as bunding) are not considered necessary and the proposed storage facilities for lube oil are considered to be BAT. However, further consideration of the capacity, design and operation of both secondary and tertiary containment systems will be addressed at the detailed design stage taking account of the site-specific local circumstances.

All lube oil tanks will be compliant with PPG2 [Ref-56].

It is not possible to provide definitive lube oil tank capacities for the purposes of the GDA process because the final selection of the emergency diesel generator sets will not be undertaken until the detailed design stage. However, for generator sets of the size and number proposed for the UK ABWR, aggregate lube oil storage of around 10,000 litres of fresh lube oil and 5,000 litres of waste lube oil might be considered typical in order to provide sufficient stock for adequate maintenance of the engines. It is also necessary to accumulate a minimum quantity of waste lube oil to in order to secure cost effective collection in bulk for recovery or reuse.

All lube oil transfers to and from the generator sets will be directly supervised and subject to procedural controls and systems in order to prevent spillages arising from over-filling. Procedures will include isolation of local drainage systems, where appropriate, and emergency spillage response measures. All operatives involved in lube oil handling and transfer will be suitably trained and their competence regularly assessed.

Purpose-designed tanker handling areas with containment systems and dedicated blind sumps will facilitate bulk deliveries of fresh lube oil and collection of waste lube oil by licensed contractor for recovery at an appropriately permitted facility. All deliveries and collections will be by road tanker. All tanker handling activities and transfers will be directly supervised and subject to procedural controls and systems, with particular attention paid to the handling of flexible transfer hoses and the containment and collection of minor spillages. Spill kits and other emergency spillage response measures will be provided at appropriate locations.

7.6.6.3 Lubrication Oil Distribution

Fresh and waste lube oil will be transferred between the tanks and the generator sets via permanent, above ground pipework systems which will provide a direct connection with each engine, thereby avoiding the need for the use of flexible, temporary hoses. All lube oil tankage and pipework systems, including flexible hoses used for the transfer of lube oil between the tanks and road tankers, will be included in the planned preventative maintenance system for regular inspection. Flexible hoses will be replaced at an appropriate frequency according to the outcomes of the inspection and maintenance regime.

7.6.6.4 Lubrication Oil Changes

All lube oil changes will be carried out by qualified and competent technicians operating an oil pump within the engine unit, which transfers the waste lube oil via above ground pipework to the dedicated waste lube oil tank. In a similar manner, the fresh lube oil tank pump is operated by the technician for transfer of fresh lube oil to each engine. The transfer will be constantly monitored by visual inspection of the engine lube oil day tank.

7.6.6.5 Oil Deliveries and Collections

All lube oil deliveries and collections will be conducted by prior agreement with the UK ABWR site and will be supervised at all times. Appropriate flexible hose connections will be used and the tanker driver will remain in attendance throughout the transfer.

Collection of waste lube oil will be conducted in a similar manner by a licensed waste contractor for subsequent recovery at a suitably permitted facility.

Deliveries and collections will be carried out in dedicated tanker handling areas with suitable hard-standing and containment systems, including a blind sump.

7.6.6.6 Boiler and Cooling System Blowdown

It will be necessary to periodically blow down the auxiliary boilers in order to maintain boiler water quality and prevent the build-up of dissolved solids which may lead to fouling of heat transfer surfaces. For manual blowdown systems, this is typically required at least daily during operation. However, some modern boilers incorporate continuous blowdown systems where boiler water is ejected from the boiler at a low flow rate on a continuous basis. Boiler blowdown water will contain the chemicals present in the selected proprietary water treatment package (or possibly, associated residues) which may present a risk of harm to aquatic systems. The management of boiler blowdown waters is described in the Water Discharge section (Section 5).

For similar reasons, and with similar potential consequences, it may be necessary to blow down the generator cooling water systems. Again, it is expected that blowdown water flows from the generator cooling systems will be relatively minor and the potential for significant impact is therefore considered to be limited.

7.6.7 Point Source Emissions to Air (HCEP & CSG)

The primary purpose of the EDG, BBG and DAG is to generate and export electricity to the UK ABWR site under emergency circumstances in order to provide power for essential safety and control systems. The generators therefore only operate intermittently and for short periods under normal circumstances, with each unit expected to operate for a total of approximately 14 hours per year, on average, for routine testing purposes (Section 7.5.1.4). It is unlikely that multiple generators will operate simultaneously under the routine testing programme.

The primary purpose of the auxiliary boilers is to generate and export steam to the UK ABWR site during start-up, shut-down, normal operation and emergency circumstances. During start-up and shutdown, the boilers provide system-critical steam (e.g., turbine gland seal) which is normally delivered from other sources within the UK ABWR site. However, they also provide steam to continuous base-load users, including process systems, frost protection systems and building HVAC systems. It is therefore expected that at least one auxiliary boiler will be operating continuously at all times at a minimum load of around 50% MCR.

Although the over-riding requirement for the combustion installation (diesel generators) is therefore the safety of the UK ABWR site, it is still necessary to consider and assess the measures for the control of point source emissions to air for the purposes of the GDA process. Since the final selection of combustion units has not yet been undertaken, the basis for this assessment under the GDA process is the current nominal selection of equipment for the UK ABWR, as described in Sections 7.4and 7.5. In the absence of specified combustion units, nominal examples of such equipment with the required capacity have been identified from the UK market in order to provide typical emissions performance for the purpose of assessing control measures and the potential for impact (see Section 7.7). It is considered that the ultimate selection of equipment will comprise either the current nominal selection or equivalent units with similar (if not identical) emissions performance and that this approach is therefore valid.

Operation under the environmental permitting regime prioritises prevention of emissions to the environment by primary techniques above their abatement by secondary techniques. This philosophy, along with a number of other factors, has been considered in the process of selecting a nominal prime mover for the generator sets required for the delivery of electricity under emergency circumstances. Likewise, a similar approach has been applied to the selection of nominal auxiliary boiler units.

Owing to the short and intermittent operating periods inherent to the provision of emergency power, it is generally accepted that secondary abatement is not BAT for this type of operation. The cost of installing and operating secondary techniques (e.g., Selective Catalytic Reduction (SCR)) is considered to be disproportionate in relation to the environmental benefit which might be delivered. For such short and infrequent operating periods, even substantial reductions in NO_x emissions are unlikely to deliver significant improvements in long term background NO_x. For short term impacts, assuming primary techniques are BAT, optimised stack height and design are likely to deliver a more cost effective mitigation measure to minimise impact.

For the auxiliary boilers, which are expected to be industry standard, conventional, package type fire tube boilers, the primary technique of fitting low NO_x burners delivers substantially lower NO_x concentrations and is widely considered to offer the optimum control measure for such units in conjunction with optimised combustion system design and configuration. Since the individual boilers have rated thermal inputs of less than 50 MW_{Th}, there are no applicable emission benchmarks either in EA guidance or the IED Annex V. For units of this size, it is usually the case that secondary abatement is considered to be a disproportionate cost in relation to the environmental benefit which might be delivered. For the UK ABWR, where the operating regime envisages only one boiler operating continuously at around 50% MCR for at least half the year, secondary abatement is unlikely to deliver a reduction in emissions which is sufficient to offer significant improvements in long term background NO_x. For short term impacts, assuming primary techniques are BAT, optimised stack height and design are likely to deliver a more cost effective mitigation measure to minimise impact.

The focus on primary techniques for the auxiliary boilers must also include the consideration of fuel selection. Boilers may be designed to operate using a wide range of fossil fuels. Whilst alternative fuels have been considered, the over-riding requirement for nuclear safety dictates that the fuel must offer security of supply for emergency circumstances. The selection of diesel allows the bulk storage of fuel on site in a liquid (and unpressurised) form. Whilst such a storage facility presents a risk to the environment, it is considered that the risk may be minimised and mitigated by suitable control and containment measures. It is therefore assessed as being a lower risk than the risk of failing to provide an adequate emergency fuel supply for the boilers for the maintenance of nuclear safety. It is less likely to be disrupted than, for example, natural gas supplied from the Grid, because storage of a liquid fuel on site allows functional isolation from dependency on Grid based supplies in the event of an emergency. It is therefore considered that the selection of diesel as the fuel for the auxiliary boilers is BAT for the primary duty in relation to the UK ABWR site and the protection of the environment.

The use of UK specification ULSD will minimise the potential for emissions of SO_2.

For the emergency and back-up generators, since secondary abatement techniques are not considered appropriate for this type of operation, the focus must also be on primary techniques and fuel selection for the protection of the environment.

The principal options for consideration as suitable prime movers for generation sets deployed on emergency standby duty are:

- Spark ignition engines.
- Compression ignition engines.
- Gas Turbines (GTs) operating in Open Cycle (OCGTs).

All these prime mover types may operate using a range of fossil fuels. However, as for the auxiliary boilers, and for the same reasons, it is considered that the selection of diesel as the fuel for the emergency and back-up generators is BAT for the primary duty in relation to the UK ABWR site and the protection of the environment.

As for the boilers, the use of UK specification ULSD will minimise the potential for emissions of sulphur dioxide.

It is acknowledged that gas turbines in OCGT mode can be BAT for certain circumstances such as emergency standby power generation for essential supplies. Whilst OCGTs are not regarded as BAT for baseload power generation, they may be accepted for emergency power generation where the over-riding priority is for short term generation of electricity for safety-related loads rather than overall generation efficiency. Hitachi-GE is aware that the EA has permitted a number of under-utilised CCGT facilities to operate in OCGT mode for STOR (short term operating reserve) duty in order to allow the operator to deploy an otherwise largely idle asset. It is therefore considered that OCGTs are likely to be BAT for emergency standby duty in certain circumstances.

Whilst the start-up time for lightweight aero-derivative OCGTs is relatively short (around fifteen minutes from stationary to full load, assuming a cold start), it is still considerably longer than the start-up time for CI (diesel) engines (which effectively offer an almost instantaneous response, even for larger units) and therefore an OCGT will not offer the same flexibility in terms of response time to a standby emergency call. Heavy duty (industrial) gas turbines are unable to match the short start-up times required for emergency standby operations, even in OCGT mode, owing to the need to bring the usually much larger turbine unit up to approximately operational speed using a diesel or electric motor starter unit prior to initiation of fuel combustion.

OCGTs will generally require higher capital investment and will have higher operating and maintenance costs than CI engines. In particular, these costs will be substantially higher where smaller, multiple GTs are specified for flexibility of operation or assurance of emergency response (such as required here for nuclear safety reasons). Gas turbines for power generation tend to be specified as larger capacity units in order to optimise efficiency by minimising mechanical transmission losses between the turbine and the generator and from the generator itself, which will be lower for a larger, single unit than for multiple, smaller units (typical OCGT electrical efficiency is in the range 35% - 42% at full load). However, a single large gas turbine generator set restricts operational flexibility in terms of delivering the emergency standby commitment, since if the turbine fails or is undergoing maintenance, the capacity for emergency power generation is lost.

It is therefore clear that, whilst OCGT prime movers may be BAT for certain circumstances, there are some disadvantages to their use for emergency standby duties, mainly in terms of operational flexibility and rapid start-up. Hitachi-GE therefore considers that OCGTs are unlikely to offer the optimum solution for the proposed UK ABWR combustion installation and that the use of reciprocating engines will offer a means of addressing the disadvantages of OCGTs for the overall delivery of BAT.

Reciprocating engines can be spark ignition (SI) or compression ignition (CI). Both types have often been used as the prime mover in small and medium scale CHP applications (< 20 MW_e) as well as for emergency and short term power generation duties such as emergency standby or STOR operations. For both types of reciprocating engine, the configuration of engine internals, such as cylinders, pistons and cylinder heads, is known to contribute to optimised NO_x performance and, coupled with a multi-function ECU (engine control unit) with a fully sensored engine set-up, emissions performance associated with BAT is likely to be delivered without the need for secondary techniques.

For power generation applications, CI engines often operate on diesel fuel or heavy fuel oil which offers independence of operation from external Grid-based supply of natural gas, with onsite bulk storage of liquid fuel. CI engines also tend to be more robust in design and construction owing to their operation at higher pressure. Being less complex in terms of combustion systems, they are also likely to be more reliable than SI engines.

Modern spark ignition engines are available which have been specifically designed for the combustion of natural gas and offer a primary technique for the control of emissions which is widely accepted as BAT. However, the dependence on off-site supply of gas from the Grid introduces a conflict with the over-riding requirement for nuclear safety which the diesel (CI) engine avoids by relying on on-site bulk storage of liquid fuel. Whilst the bulk storage of liquid hydrocarbon fuel introduces a risk to the environment, it is considered that this risk may be minimised and mitigated and is, in any case, outweighed by the risk to nuclear safety which dependence on offsite Grid supplied fuel introduces.

Hitachi-GE has therefore concluded that multiple, independent CI generator sets, firing on UK specification ULSD, offer an optimum, industry standard solution and are therefore considered to be BAT for the UK ABWR requirement for emergency and back-up power supply.

Owing to the intermittent and short term nature of emergency power generation, Hitachi-GE considers that recovery of heat from the engines for operation as a CHP is not technically or economically feasible. In addition, the design of the UK ABWR does not include suitable customers within the wider ABWR site for the intermittent and short term supply of relatively low grade heat. It has therefore been concluded that heat recovery for CHP operation at the UK ABWR combustion installation is not BAT.

In line with the philosophy which requires that prevention of emissions to the environment by primary techniques will be prioritised, the following control measures will be implemented at the installation.

The objective of the primary in-process controls will be to maintain the engine units in peak operating condition in order to deliver the site's emergency power requirements whilst achieving optimum emissions in line with manufacturer's performance specification for the units.

The in-process controls that will be in place on the engine units primarily consist of those required for the control of emissions to air and management of energy efficiency. Such controls will include:

- Plant design (including combustion chamber, piston crown and valve configuration).
- Manual and automatic tuning.
- Process parameter monitoring.
- Planned preventative maintenance and corrective action.
- The use of UK specification ULSD in order to minimise the potential for emissions of sulphur dioxide.

There will be no secondary abatement in place since such techniques are not considered to be BAT for short term emergency standby operation. All necessary control of emissions will be achieved through the primary in-process controls.

All of the controls identified above are discussed further in the following sections.

7.6.7.1 Plant Design

Through research and development, engine manufacturers have found that combustion chamber design (including cylinder, piston crown and valve configuration) affects combustion efficiency and exhaust emission levels. Consequently, they have developed a range of combustion chamber configurations for specific applications, thereby providing inherent control of exhaust emissions and energy efficiency.

Likewise, modern boiler configurations and the use of techniques such as Low-NO_x Burners (LNBs) provide control of combustion exhaust emissions and energy efficiency.

Whilst the final selection of the generator engines and auxiliary boilers is not yet determined, the installed engines will have performance which is at least equivalent (and, potentially, better) than the nominal engine selection.

7.6.7.2 Tuning

Manual and automatic tuning of combustion units (especially the generator engines) provide the means for maintaining peak performance to control exhaust emissions at the required levels, whilst also providing consistently good combustion and energy efficiency.

7.6.7.3 Process Monitoring and Corrective Action

To control the combustion conditions within the engine, an electronic engine management system (or ECU) is used. The key parameters recorded by the control systems that are used to manage the operation of the engines (and hence may be considered to be surrogate environmental monitors) are listed in the following bullet points:

- Fuel flow rate to each engine.
- Fuel delivery system pressure.
- Air flow rate, temperature and pressure.
- Cylinder temperatures and pressures.
- Oil temperature and pressures.

These measurements are used by the ECU to adjust the engine ignition timing, air flow from the turbocharger and temperatures in the engine's system. The engines are designed to operate in lean burn mode thereby reducing emissions of NO_x. If any of the measured process parameters exceeds levels specified in the process control manuals, an alarm is raised, requiring operator action. In a serious fault condition (e.g., inconsistent fuel supply, electrical distribution failure), the plant would shut down to prevent uncontrolled emissions. For less serious fault conditions, once the fault is cleared, the engine would automatically restart. If necessary, maintenance technician site attendance will be requested.

During start up and shut-down, engine emissions may vary but the time taken for the plant condition to stabilise is relatively short (typically 15 minutes from cold start to normal operating temperature) and any peak emissions would therefore also be short term.

Control of combustion conditions in the auxiliary boilers will be achieved through conventional boiler control systems, utilising computerised systems and digital interfaces wherever appropriate for optimum efficiency and emissions performance.

7.6.7.4 Maintenance and Corrective Action

Maintenance is a key component of operational control at the installation, particularly for ensuring air emissions and energy efficiency are maintained at the required levels. Maintenance activities are typically planned or reactive (i.e., in response to breakdowns or performance deterioration resulting from a fault). Planned maintenance ensures that regular inspections are carried out to maintain optimal performance. The reactive maintenance ensures that unexpected maintenance issues are quickly resolved.

All regular maintenance will be completed on the time scale specified by the equipment manufacturer. Oil changes and services are normally programmed on the basis of operating hours for engines of this type. However, where operating hours are so low, it is more likely that oil change and servicing intervals will be determined on the basis of elapsed time and sampling and analysis of engine oil. A high level of preventative maintenance is designed to avoid unscheduled down time, maximising the plant availability and its ability to control emissions and maintain an efficient level of operation between overhauls.

Chemical analysis of the engine lube oil is expected to be carried out on a regular basis and will form part of the planned preventative maintenance regime. It is an important component of the proposal not to undertake annual emissions monitoring and to rely instead on the demonstration of regular and effective planned preventative maintenance in order to keep the engines at peak efficiency and optimum emissions performance. The lube oil analysis will indicate when oil needs changing and can show possible wear or defects to engine components which may detract from engine performance.

7.6.7.5 Emissions to Air

The purpose of planned preventative maintenance is to ensure that the engines continue to operate at peak efficiency so that emissions are controlled to the optimum levels. This is achieved by using planned maintenance periods that are consistent with the maintenance requirements of the engines. The maintenance requirements are usually specified by the manufacturer but may be adjusted based on previous experience in operating and maintaining the installed engine units. The maintenance activities for air emissions control include such items as engine tuning, valve settings, air filter inspection/replacement, lube oil and oil filter changes, etc.

7.6.7.6 Energy Efficiency

Maintenance of the engine and electricity generator mechanical components ensures that there are minimal frictional losses from worn parts.

7.6.7.7 Preventative Maintenance Audit

It is expected that, in order to ensure ongoing effectiveness of the planned preventative maintenance system, it will be regularly audited to identify potential improvements. The audits will consider reactive maintenance that has been required and feedback from planned preventative maintenance activities. The output from the audit process will be used to determine changes required to the maintenance procedures and schedules. The purpose of such changes will be to improve the operational effectiveness of the plant.

7.6.7.8 NO_x Control

The primary pollutant of concern for both the generator engines and the boilers is NO_x.

The most important oxides of nitrogen with respect to releases from combustion processes are nitric oxide (NO), nitrogen dioxide (NO_2) (together comprising NO_x) and nitrous oxide (N_2O). Nitric oxide forms over 95% of the total NO_x in emissions from most types of combustion plant.

There are three recognised NO_x formation mechanisms:

- 'Fuel NO_x' by conversion of chemically bound nitrogen in the fuel.
- 'Thermal NO_x' by fixation of nitrogen in the combustion air.
- 'Prompt NO_x' by a mechanism in which molecular nitrogen is converted to NO via intermediate products in the early phase of the flame front with hydrocarbons participating in the reactions.

The first two mechanisms are the only ones of major importance in most combustion plants.

Fuel NO_x formation depends on the oxygen level in the vicinity of the flame, therefore controlling and reducing oxygen levels to the minimum possible reduces fuel NO_x. Thermal NO_x formation requires temperatures greater than 1,000°C, therefore reducing peak temperatures below this value reduces thermal NO_x formation. The thermal NO_x formation route is the most important source of NO_x emissions from oil and gas fired plant.

Baseline NO_x emissions from unabated internal combustion (reciprocating) engines vary with engine size and speed. Larger, lower speed engines will generally produce more NO_x than smaller high-speed engines

Applying combustion modifications is limited by operational and fuel specific parameters and the influence on the safe operation of plant. As a result of the likely changes in one or more of these parameters, the suitability and choice of a primary measure and the resulting effects may not be directly transferable from one type of plant to another.

All of the above factors will be taken into consideration when selecting suitable plant for the required combustion installation duty at the UK ABWR. In particular, for the auxiliary boilers, techniques such as control of excess air, LNBs, over fire air, flue gas recirculation/reburn will be considered, where appropriate, having regard for technical and economic feasibility in the context of the benefit delivered.

For the generator engines, the principal techniques for NO_x control include:

- Combustion chamber, piston crown and valve configuration.

- Lean burn technology.
- Optimised fuel/air mixing (usually via multiple injectors).
- Reduced air injection manifold temperature by increased intercooling.
- Tuning for minimum NO_x emissions (but note that this may increase emissions of CO and VOC).
- Reduction of charge temperature via water injection (although this is often impractical and may introduce a significant risk of engine corrosion).
- Exhaust gas recirculation.

Of these techniques, most modern diesel generator engines utilise lean burn technology, combustion chamber design and optimised fuel / air mixing. Virtually all engines use turbo charging with intercooling.

Emissions from the nominal emergency diesel generator output assumed for the UK ABWR for the purposes of assessing potential stack height and environmental impact via screening level assessment have been based on data from Caterpillar, one of the market leaders in the manufacture of power generation equipment. Specifically, two V-16, 4-stroke water-cooled diesels are considered to be representative:

- The standby diesel generator set 5720 kW_e 7150 kVA, (the 'C3616') for the EDGs.
- The standby diesel generator set 2400 kW_e 3000 kVA, (the 'C175') for the BBGs.

For the engines, the impact assessment uses the NO_x emissions quoted by the manufacturer on the technical specifications for the respective engines, pro-rata'd as appropriate to the required engine output, i.e.:

- 12.94 g/bkW-h for the C3616 (equivalent to approximately 2,309 mg/Nm^3);
- 1,500 mg/Nm^3 for the C175.

In practice, the engines selected for the UK ABWR site are may deliver lower NOx emissions, based on the values quoted in [Ref-61]. This states that, for a medium speed engine over 20 MW_{Th} using heavy or light fuel oil, an emission limit value for oxides of nitrogen of 1850 mg/Nm3 can be reached by using primary measures such as an optimised low-NO_x engine.

For the auxiliary boilers, a NO_x emission of 300 mg/Nm^3 has been assumed. This is the benchmark for 50 to 100 MW_{Th} combustion plant from the EA guidance note 'Combustion Activities EPR 1.01' and is therefore not strictly applicable to these units (rated thermal input of 24.1 MW_{Th}). However, it has been adopted as a worst case scenario for the purposes of assessing the impact of the boilers (see Section 7.7 for further details). In practice, the boilers selected for the UK ABWR site may deliver lower NO_x emissions.

It is also necessary to take into account the normal operating pattern of the emergency and back-up generators whereby they will each operate for between 12 and 14 hours per year, on average (Section 7.5.1.4). The routine testing programme is based on regular hourly runs with a 24-hour run every 18 months. The impact assessments undertaken (described in Section 7.7) assume operation of the EDGs and BBGs simultaneously (the emergency scenario) which is expected to be an extremely rare event. Under normal circumstances (routine testing), it is expected that the generator sets will run independently with no multiple operation. It is therefore considered that the basis of the assessment is extremely conservative and is, in fact, delivering a substantial over-estimate of the likely impacts.

Whilst short term impacts are likely to be of greatest concern under the normal operating pattern, the routine testing programme mostly involves very short runs where any potential impacts which might occur will be both transitory and extremely short-lived. Overall, it is therefore expected that planned operation of the emergency and back-up generators are unlikely to lead to any significant impacts.

7.6.7.9 SO_2 Control

It is expected that SO_2 emissions from the combustion installation at the UK ABWR site will be controlled via the primary technique of fuel selection, where it has been assumed that UK specification ULSD will be used (0.001% sulphur by weight, in accordance with BS EN 590).

For the purposes of the impact assessment, SO_2 emissions have been calculated using the fuel consumption rates and the ULSD sulphur content, since the SO_2 emission rate is substantially dependent on these factors.

For the emergency generators, whilst short term SO_2 impact has not been screened out, this is considered to be a substantial over-estimate, as discussed in Section 7.6.7.8 for NO_x emissions.

7.6.7.10 CO Control

CO emissions from the generator engines will be minimised by combustion efficiency techniques, such as combustion chamber design, optimised fuel / air mixing and engine tuning for optimum NO_x/CO balance.

Likewise, CO emissions from the auxiliary boilers will also be minimised by combustion efficiency techniques.

For the engines, the impact assessment uses emission rates in the manufacturer's specifications while the EPR1.01 benchmark was used for the boilers.

Whilst the assessment of potential impact arising from the operation of the UK ABWR combustion installation indicates that CO emissions may not be screened out for operation of the EDGs, it is considered unlikely in reality that CO emissions will lead to significant impact (see Section 7.7).

7.6.7.11 VOC Control

The emission of VOCs from both the emergency generator engines and the auxiliary boilers will be controlled in the same way as CO emissions, i.e., via combustion efficiency techniques.

7.6.7.12 Particulates Control

For liquid fuelled combustion plant, as is the case for the UK ABWR combustion installation, the control of particulate emissions is a key factor. Once again, control is mainly dependent on those measures which secure optimised combustion efficiency, since particulate production is typically a function of incomplete or inefficient combustion. However, for the generator engines in particular, prevention of particulate emissions is especially dependent on fuel quality. Since it is proposed to utilise UK specification ULSD at the UK ABWR combustion installation, the selection of modern compression ignition diesel engines should lead to low emissions of particulate.

For the engines, the impact assessment uses emission rates in the manufacturer's specifications while the EPR1.01 benchmark was used for the boilers.

Although the screening level impact assessment did not screen out particulate emissions (PM_{10}) for short term impacts for both the emergency generators and the auxiliary boilers (see Section 7.7), it is anticipated that further detailed air quality dispersion modelling will show that significant impacts are unlikely to occur at sensitive off-site receptors.

7.6.7.13 CO_2 Control

CO_2 is not a pollutant which is specified for control under the EPR [Ref-16], as amended [Ref-47]. However, all measures for the reduction of fuel use, i.e., those measures described above for the optimisation of combustion efficiency, will inherently reduce CO_2 emissions.

7.6.8 Fugitive Emissions (HCEP & CSG)

The UK ABWR combustion installation will incorporate control measures and pollution prevention measures for the prevention of fugitive releases which are in line with indicative guidance and BAT.

All bulk hydrocarbon storage facilities will be provided with appropriate primary, secondary and tertiary containment measures for the prevention of fugitive releases to water, groundwater or the underlying ground arising from loss or spillage. In addition, procedural controls and emergency response measures will be implemented which will be applied via direct supervision to all handling activities involving hydrocarbons (principally diesel and engine lube oil).

Fugitive emissions to air are expected to be limited to low level breathing losses of volatiles from the bulk storage of diesel and further measures to control such emissions are not considered proportionate. There is the potential for fugitive emissions from the emergency generator engine crank case breathers (known as blowby). However, modern diesel engines are usually equipped with closed crankcase ventilation systems for the control of these emissions and this is therefore unlikely to present an issue in relation to fugitive releases to air.

7.6.9 Monitoring (HCEP & CSG)

It is not expected that there will be direct emissions to water from the combustion installation at the UK ABWR and monitoring is therefore not proposed for releases to water or sewer.

For the purposes of the GDA process, it is assumed that all aqueous emissions from process sources (including cooling water systems and boiler blowdown) and surface water run-off (including firefighting water and storm water) will be directed to drainage and effluent systems within the wider UK ABWR site (Section 5). It is therefore anticipated that monitoring of discharges to water (or sewer) will be associated with the releases from these systems in accordance with other permit requirements and additional monitoring of the release from the combustion installation is therefore considered to be disproportionate.

It is recognised that periodic emissions monitoring for releases to air from a facility such as the UK ABWR combustion installation would be required on an annual basis. It is proposed that annual monitoring (manual stack test) is undertaken for the diesel generators and the auxiliary boilers for NO_x, CO and particulate matter (PM). It is proposed that SO_2 emissions are not measured directly, but that they are calculated on the basis of the sulphur content of the fuel used, assuming a conservative 100% conversion of fuel sulphur to SO_2. A continuous emissions monitoring system (CEMS) is not considered appropriate. On the basis that the sets of the combustion plant (EDGs, BBGs and the auxiliary boilers) are identical (and subject to identical operating and maintenance regimes), then only one of each set would require monitoring in each year. Therefore it is proposed that each of the 3 x EDG and 1 x DAG are tested once every four years, and each boiler is tested every two years. Monitoring will be undertaken in accordance with Technical Guidance Note TGN M2 (monitoring of stack emissions to air). Personnel/organisations undertaking the monitoring will do so in accordance with the requirement of the EA Monitoring and Certification Scheme (MCERTS).

During commissioning, extensive monitoring of the exhausts will be conducted to correlate emission performance with key combustion parameters, which will then act as surrogate measures to demonstrate compliant emissions.

Although it is considered unlikely that visible emissions will occur, Hitachi-GE also proposes to undertake periodic visual monitoring for visible emissions, at an appropriate frequency during operation of the combustion installation. Records will be retained on site in accordance with permit conditions relating to record keeping.

It is considered that environmental monitoring beyond the UK ABWR combustion installation in relation to emissions of combustion gases would be disproportionate and none is proposed.

Process variables will be continuously and comprehensively monitored as they are critical to the efficient operation of the UK ABWR combustion installation. Data to be monitored and recorded will include fuel usage and energy generation.

7.6.10 General Management Condition (HCEP)

Prior to the commencement of operations at the UK ABWR combustion installation, Hitachi-GE will develop and implement a written management system which will be commensurate with the risk and complexity of the activities. It is recognised that the management system is key to the demonstration of how effectively the environment is being protected and the maintenance and further improvement of the control of environmental risks presented by the activities within the combustion installation.

It is likely that the management system for the combustion installation will be an integral component of the wider UK ABWR site management system which will be designed to control and manage the operation of the entire nuclear facility. However, specific procedures will be incorporated which relate to the particular aspects of the combustion installation, where appropriate.

7.6.10.1 Management System

It is intended that the design and development of the management system at the UK ABWR will deliver the following aspects, in addition to contributing more generally to the improvement of the wider business:

- Compliance with the environmental permit and other environmental legislation.
- Demonstration of Hitachi-GE's commitment to protecting the environment.
- Enhanced protection of the environment and human health.
- Identification, provision and recording of all staff training, including training which is especially targeted at the management and control of specific environmental aspects.
- Delivery of a structured programme of maintenance for plant and infrastructure, in particular, plant and equipment whose failure has the potential to lead to environmental impacts.
- Development of management techniques which deliver more consistent and more efficient site operations.
- Management behaviours which develop a reputation as a good neighbour.
- Development of cost saving practices, such as resource efficiency techniques, recycling activities, waste reduction measures, etc.

7.6.10.2 Type of Management System

At this stage of the project development, no decision has been taken by Hitachi-GE regarding the type of management system which might be implemented at the UK ABWR site. Whilst an in-house system may be adopted, it is more likely that an externally certified system will be implemented, probably either BS EN ISO14001 (a globally recognised and acknowledged standard, which is widely used) or EMAS (Eco Management and Audit Scheme), which was originally a European Standard but is now available to organisations outside Europe.

If an externally recognised management system is adopted, Hitachi-GE will utilise an external independent certification body to verify conformance to the requirements of the standard or scheme. Certification and verification helps to provide independent assurance of the performance of the management system and demonstrates that system has passed a high level of scrutiny. Hitachi-GE note that the EA recommend that the certification or inspection body should be accredited by the United Kingdom Accreditation Service (UKAS), or an equivalent National Accreditation Body (NAB) for certification bodies based outside the UK, for the specific standard or scheme they audit against. This provides additional assurance that verification audits are carried out to recognised standards.

Hitachi-GE also recognises that the use of an external certified Environmental Management System (EMS) does not mean automatic compliance with all permit conditions and that it is important to review the permit and management system thoroughly to ensure that all conditions are covered by the system which is implemented.

7.6.10.3 Content of Management System

The selected management system to be implemented prior to commencement of operations will incorporate procedures and systems which cover the following aspects, in accordance with guidance:

- Site plans.
- Operations.
- Maintenance.
- Accidents and incidents.
- Site security.
- Non-compliance and non-conformance.
- Closure.
- Complaints, including a mechanism for investigation of all complaints.
- Provision of sufficient, and sufficiently competent, staff and other resources.
- Provision of appropriate training.
- Emissions and monitoring.
- Record keeping.
- Access to a copy of the permit for all staff and contractors.

7.6.11 Site Security (HCEP)

Site security for the UK ABWR combustion installation will be delivered by the measures implemented for the security of the wider UK ABWR site, which will be commensurate with the character of the site (i.e., a nuclear power station). Additional security measures for the combustion installation itself are not considered appropriate.

7.6.12 Control of Odour, Noise and Vibration (HCEP)

A detailed assessment of the potential for odour, noise or vibration has not yet been undertaken at this stage.

However, it is not considered that specific measures beyond those normally specified by indicative guidance for the control of odour will be required at the UK ABWR combustion installation. There are no sources within the site which are likely to generate odour strong enough to be detected beyond the installation boundary or the wider UK ABWR site boundary. It is therefore considered unlikely that an odour management plan will be necessary.

All equipment for the combustion installation will be specified with suitable noise or vibration attenuation measures where these are considered appropriate. For example, the generator engine exhausts and boiler pressure relief valves will be equipped with appropriate silencing equipment in order to attenuate noise emission levels. In addition, the generator engine mounting systems will be designed at the detail engineering stage to minimise the potential for transmitted vibration.

7.6.13 Emission Benchmarks (CSG)

Whilst the UK ABWR combustion installation has an aggregate rated thermal input of over 50 MW_{Th} (132.48 MW_{Th}), none of the combustion units individually exceed 50 MW_{Th}. Emission benchmarks set out in guidance or relevant legislation are all targeted at combustion units larger than 50 MW_{Th} and are therefore not applicable to the units which comprise the UK ABWR combustion installation.

Furthermore, IED Article 30(8) specifically excludes diesel engines from the emission limit values set out in Parts 1 and 2 of IED Annex V and these limits may therefore not be considered for the emergency or back-up generators.

Hitachi-GE therefore considers that there are no relevant emission benchmarks for the UK ABWR combustion installation.

7.6.14 Industrial Emissions Directive [2010/75/EU]

Chapter III of the IED [Ref-48] sets out special provisions for Combustion Plants where the rated thermal input is greater than 50 MW_{Th}, in accordance with Article 28:

This Chapter shall apply to combustion plants, the total rated thermal input of which is equal to or greater than 50 MW, irrespective of the type of fuel used.

Since the aggregate rated thermal input of the combustion installation proposed for the UK ABWR is greater than 50 MW_{Th} (132.48 MW_{Th}), it is necessary to consider whether the installation might be subject to IED Chapter III requirements.

The total rated thermal input of the UK ABWR combustion installation is derived from a simple aggregation of the capacities of the individual units. It is therefore necessary to consider the specific aggregation rules set out by IED Article 29 for multiple combustion units in order to determine whether the 50 MW_{Th} threshold is exceeded for the purposes of the Directive.

The Article 29 aggregation rules are as follows:

1. *Where the waste gases of two or more separate combustion plants are discharged through a common stack, the combination formed by such plants shall be considered as a single combustion plant and their capacities added for the purpose of calculating the total rated thermal input.*
2. *Where two or more separate combustion plants which have been granted a permit for the first time on or after 1 July 1987,or the operators of which have submitted a complete application for a permit on or after that date, are installed in such a way that, taking technical and economic factors into account, their waste gases could in the judgement of the competent authority, be discharged through a common stack, the combination formed by such plants shall be considered as a single combustion plant and their capacities added for the purpose of calculating the total rated thermal input.*
3. *For the purpose of calculating the total rated thermal input of a combination of combustion plants referred to in paragraphs 1and 2, individual combustion plants with a rated thermal input below 15 MW shall not be considered.*

Only the auxiliary boilers will discharge waste gases through a common stack which exits through the HB/B roof but since the aggregate rated thermal input for these units is only 48.2 MW_{Th}, the 50 MW_{Th} threshold is not exceeded and therefore IED Chapter III does not apply.

All the EDG, DAG and BBGs are to have individual stacks. It is considered that the generator units should be entirely separate and independent on safety grounds in order to provide security of supply in the event of an emergency and individual stacks are therefore regarded as essential. In addition, the proposed locations of the combustion units are separated between the three EDG buildings (each containing one EDG) and the back-up building (containing two BBGs). Although the ultimate location of the DAG is yet to be determined, it is expected that it will be located in a separate building for the same reasons as described above.

It is clearly not technically or economically feasible to install common flues for units located in separate buildings at some distance apart. Hitachi-GE therefore consider that, taking technical, economic and nuclear safety factors into account, it is unlikely that the application of Article 29(2) could be justified by the competent authority (the EA) and the capacities of the individual units should not be added for the purpose of calculating the total rated thermal input under the Directive.

Within the back-up building, the BBGs are physically separated to minimise the risk of both units being physically disabled or damaged by a common factor. Whilst it may be technically feasible to install a common stack for the discharge of waste gases, this would compromise the principle of separation and independence which is intended to maintain security of supply. Provision of a common, multi-flue stack has therefore been ruled out but, in any case, the BBGs only aggregate to 12.28 MW_{Th}, which is well below the 50 MW_{Th} threshold. Each unit is also less than the 15 MW_{Th} rated input threshold as set out by Article 29(3) and they may therefore be discounted from consideration.

The UK ABWR combustion units are therefore not to be considered as a single unit under IED Article 29.

However, even if it were to be the case that IED Chapter III applied to the proposed UK ABWR combustion installation, Article 30(8) states the following:

The emission limit values set out in Parts 1 and 2 of Annex V shall not apply to the following combustion plants:

(a) Diesel engines.

Since the emergency and back-up generator sets are all diesel units, under Article 30(8), the emission limit values set out in IED Annex V would not, in any case, be applicable.

7.7 Impact Assessment

The aim of this section is to provide details of the impact assessment of the emissions to air from the combustion installation for the UK ABWR generic design, and to demonstrate that the emissions that occur can be managed with appropriate engineering controls to reduce the potential impacts to acceptable levels.

The data used to determine the flue gas characteristics has been based on Hitachi-GE information provided for the GDA assessment, supplemented with data from equipment specifications provided by a typical manufacturer of engines and boilers of the size required within the UK ABWR generic design (in the absence of a final selection of combustion plant).

The following items of combustion plant equipment have been considered in this impact assessment:

- 3 × standby Emergency Diesel Generators (EDGs), located in individual buildings separate to the reactor building (R/B);
- 2 × Diesel driven Back-up Building Generators (BBGs), located in the Back-up building; and
- 2 × auxiliary boilers, located in the House Boiler Building (HB/B).

A DAG also forms part of the combustion installation. As discussed with the Environment Agency the DAG has not been included in the impact assessment as it will only run in place of the EDGs. The DAG has been assumed to be of a similar size to an EDG. Ultra Low Sulphur Diesel (ULSD) has been assumed as the fuel source for all combustion plant. A possible exception to this is the DAG, which could be a gas fired unit; however this will be determined at the site-specific stage.

7.7.1 Methodology

The main process emissions associated with combustion of ULSD in engines and boilers are NO_x, CO, particulate matter and relatively minor amounts of SO_2. These emissions may be released either continuously or intermittently from point sources, according to the mode of operation.

Evaluation of the potential impact of these emissions to ground level receptors has been undertaken using two screening assessments:

- Screening assessment of the main process emissions (NO_x, CO, particulate matter and SO_2), using the Environment Agency's Horizontal Guidance Document H1 [Ref-62] method.
- Further screening assessment using the USEPA's regulatory atmospheric dispersion model AERMOD (version 14134) of the short term NO_x emissions from the diesel generators. This assessment was undertaken to investigate further the anomalous value reported by the H1 assessment for the short term NO_x emission from the diesel generators.

The stack height determination and screening assessments undertaken therefore comprised:

- Data gathering to identify stack discharge characteristics for each source, building layouts and ambient background concentrations (Section 7.7.2);
- D1 stack height calculations for full load operation to identify a minimum stack height recommendation (Section 4). Undertaken using Her Majesty's Inspectorate of Pollution (HMIP) D1 stack height calculation method [Ref-63];
- H1 screening assessment to determine conservative estimates of the maximum ground level concentrations of the main combustion products (NO_x, CO, particulate matter and SO_2) (Section 7.7.4); and
- Screening assessment using the air dispersion model AERMOD to provide greater detail on the short term ground level concentration of NO_x released from the EDG and BBG (Section 7.7.5).

It should be noted that short-term ground level concentrations are of most relevance to this assessment for the diesel generators (engines) given the nature of the equipment and its intended operating pattern (standby/backup/emergency use only).

7.7.2 Data Gathering

7.7.2.1 Stack parameters

The first step in the assessment process was to establish the conditions under which the pollutants would be emitted from the diesel generator and boiler exhaust stacks. These input parameters for the assessment are presented in presented in:

- Table 7.7-1 for a single EDG,
- Table 7.7-2 for a single BBG and
- Table 7.7-3 for the auxiliary boilers (twin flue).

It should be noted that for the purposes of these calculations, the manufacturer's engine efficiency for both the EDGs and BBGs has been applied, i.e. the ratio of thermal input to electrical output as determined from the technical data sheet. For the EDGs, this has been used to factor up to the higher engine capacity required for the UK ABWR.

It is also noted that the impact assessment presented in this section (Section 7.7) is based on manufacturer's data of diesel generators that are available currently. It is expected that different plant will be available at site procurement stage, with potentially different efficiencies and emissions to those assessed here.

The identification of combustion plant in this assessment does not preclude or limit the selection of different plant at the site-specific stage.

7.7.2.2 Dataset for the EDG

The stack parameters used in the assessment of the EDG have been derived from the technical specification for Caterpillar's CAT3616 engine of 5,720 kWe output, by factoring the fuel and air flow based on the required power output of 7,200 kWe and using mass balance calculations.

Of the commercially available plant for which performance specification details could be obtained, the CAT3616 engine was the closest available to the performance requirements identified for the UK ABWR.

7.7.2.3 Dataset for the BBGs

For the BBG, the manufacturer's technical specification for the CAT175-16 standby diesel engine of 2,400 kWe output was applied. As the output from this engine was the same as that identified for the UK ABWR no factoring was required.

7.7.2.4 Dataset for the Auxiliary Boilers

Hitachi-GE data was used to provide the input parameters for the auxiliary boilers.

Table 7.7-1: Plant Design and Stack Emissions Characteristics for Standby Emergency Diesel Generator (EDG)

Parameter	Value	Source / Comment
Rated thermal input, MW_{Th}	~18	Based on Hitachi-GE required power output and typical efficiencies of modern engines
Electrical output, MW_e	7.2	Hitachi-GE
Efficiency, % electrical	40	Based on CAT3616 data sheet
Rated voltage, V	6,900	Hitachi-GE
Rated current, A	753	Hitachi-GE
Rated power factor	0.8	Hitachi-GE
Discharge velocity, m/s	23.41	Calculated from actual flow rate and diameter
Oxygen content of flue gas, % vol (dry basis)	14.2	Mass balance calculation
Fuel molecular weight, kg/m^3 @ 15°C	845	As per standard diesel fuel specification BS EN590
Fuel mass flow rate, kg/h	1,487	Based on CAT3616 specification then factored (good agreement with Hitachi-GE value of 1800 kg/h for typical EDG)
Combustion air flow rate, kg/hr	48,942	Based on CAT3616 data sheet then factored
Flue gas discharge temperature, °C	395	From CAT3616 data sheet (Hitachi-GE provided figure of 500°C for typical EDG)
Stack diameter, m	1.2	Notional value to achieve a likely efflux velocity of around 20 m/s
Oxygen content of flue gas, % vol (dry basis)	14.2	From mass balance calculation

Parameter	Value	Source / Comment
Actual discharge flow rate, am^3/s	26.48	From mass balance calculation
Normalised flow rate, Nm^3/s	11.68	Calculated from actual flow
Oxides of nitrogen (as NO_2), g/bkW-hr	12.94	From CAT3616 data sheet
Oxides of nitrogen (as NO_2) conc, mg/Nm^3	2,216	Calculated from normalised flow rate
Oxides of nitrogen (as NO_2) emission rate, g/s	25.88	Calculated from required 7,200 bkW output
Sulphur dioxide conc., mg/Nm^3	0.71	Calculated from emission rate and normalised flow rate
Sulphur dioxide emission rate, g/s	0.008	Calculated from fuel consumption rate and diesel fuel specification: S content <10 mg/kg
Carbon monoxide, g/kW-h	0.81	From CAT3616 data sheet
Carbon monoxide, mg/Nm^3	139	Calculated from normalised flow rate
Carbon monoxide emission rate, g/s	1.62	Calculated from required 7,200 bkW output
Particulate matter, g/bkW-hr	0.13	From CAT3616 data sheet
Particulate matter conc., mg/Nm^3	22.3	Calculated from normalised flow rate
Particulate matter emission rate, g/s	0.26	Calculated from required 7,200 bkW output

Table 7.7-2: Plant Design and Stack Emissions Characteristics for Backup Building Generator (BBG)

Parameter	Value	Source / Comment
Rated thermal input, MW_{Th}	6.14	Based on CAT175-16 data sheet
Electrical output, MW_e	2.4	Hitachi-GE
Efficiency, % [electrical]	39	From CAT175-16 data sheet
Rated voltage, V	690	Hitachi-GE
Rated current, A	2,510	Hitachi-GE
Rated power factor	0.8	Hitachi-GE
Fuel molecular weight, kg/m^3 @ 15°C	845	As per standard diesel fuel specification BS EN590
Fuel mass flow rate, kg/h	520	From CAT175-16 data sheet
Combustion air flow rate, kg/hr	13,428	From CAT175-16 data sheet
Flue gas discharge temperature, °C	485	From CAT175-16 data sheet (agrees with Hitachi-GE supplied figure of 500°C for typical EDG)
Stack diameter, m	0.7	Notional value set to achieve likely efflux velocity
Discharge velocity, m/s	21.57	Calculated using diameter and flow rate
Oxygen content of flue gas, % vol (dry basis)	12.3	From mass balance calculation
Actual discharge flow rate, am^3/s	8.30	From mass balance calculation
Normalised flow rate, Nm^3/s	4.11	Calculated from actual flow rate
Oxides of nitrogen (as NO_2) conc., mg/Nm^3	1,500	Equivalent figure at 15% oxygen (dry basis) to the value reported in the CAT175-16 data sheet (4,104 mg/Nm^3 at reference conditions of 5% oxygen).
Oxides of nitrogen (as NO_2) emission rate, g/s	7.54	Calculated from normalised flow rate
Sulphur dioxide conc., mg/Nm^3	0.71	Calculated from emission rate and normalised flow rate
Sulphur dioxide emission rate, g/s	0.003	Calculated from fuel consumption rate and diesel fuel specification: S content <10 mg/kg
Carbon monoxide conc., mg/Nm^3	153	From CAT175-16 data sheet
Carbon monoxide emission rate, g/s	0.43	Calculated from normalised flow rate
Particulate matter conc., mg/Nm^3	10.4	From CAT175-16 data sheet
Particulate matter emission rate, g/s	0.063	Calculated from normalised flow rate

Table 7.7-3: Plant Design and Stack Emissions Characteristics for Auxiliary Boiler

Parameter	Value	Source / Comment
Rated thermal input, MW_{Th}	24.1	Provided by Hitachi-GE, based on typical boiler of 32 t/h steam
Electrical output, MW_e	n/a	-
Steam production rate, t/h	32	Hitachi-GE, per boiler
Efficiency, % [thermal]	90	Hitachi-GE
Fuel molecular weight, g/mol	180	Hitachi-GE
Fuel mass flow rate, kg/h	2,607	From mass balance calculation, per boiler
Flue gas discharge temperature, °C	170	Hitachi-GE
Stack diameter, m	1.5	Hitachi-GE for a single flue with two boilers
Discharge velocity, m/s	14.1	Calculated from stack diameter and volumetric flow rate for two boilers (Hitachi-GE provided figure of 21 m/s, considered high)
Oxygen content of flue gas, % vol (dry basis)	2.6	From mass balance calculation for two boilers (agrees with Hitachi-GE figure of 2.5%)
Operational excess air, %	15	Hitachi-GE
Actual discharge flow rate, am^3/s	25.0	From mass balance calculation, for two boilers (agrees with Hitachi-GE figure of 12.16 am^3/s per boiler)
Normalised flow rate, Nm^3/s	13.6	Calculated from actual flow, at 3% oxygen (dry basis), for two boilers
Oxides of nitrogen (as NO_2) conc., mg/Nm^3	300	From EPR 1.01 for combustion plant 50-100 MW_{Th}
Oxides of nitrogen (as NO_2) emission rate, g/s	4.06	Calculated, for two boilers emitting via a single flue
Sulphur dioxide conc., mg/Nm^3	2.1	Based on fuel sulphur content of 10 mg/kg and fuel mass flow rate
Sulphur dioxide emission rate, g/s	0.03	Calculated, for two boilers emitting via a single flue
Carbon monoxide conc., mg/Nm^3	150	From EPR 1.01 for combustion plant 50-100 MW_{Th}

Parameter	Value	Source / Comment
Carbon monoxide emission rate, g/s	2.03	Calculated, for two boilers emitting via a single flue
Particulate matter conc., mg/Nm^3	15	From EPR 1.01 for combustion plant 50-100 MW_{Th}
Particulate matter emission rate, g/s	0.20	Calculated, for two boilers emitting via a single flue

7.7.2.5 Building Dimensions

Building dimension details have been taken from an indicative layout and dimensions of the main facility structures, based on the generic site.

The layout and orientation of buildings is important when undertaking the D1 stack height calculation and H1 screening assessment. Of particular importance are the dimensions of the largest, nearby structures. The building heights and dimensions were provided by Hitachi-GE for the key on-site structures; these are shown in Table 7.7-4.

Table 7.7-4: Dominant Plant Structures

Structure	Height (m)	Dimensions (m)
Reactor building	42.3	59 x 61
Control building	16.5	42 x 58
Turbine building	33.9	69 x 113
Radioactive waste building	21.5	31 x 52
Backup building	23.2	44 x 44
Service building	21.8	61 x 43
House Boiler Building (HB/B)	15.0	60 x 26
EDG building no.1	14.3	26.5 x 18.5
EDG building no.2	14.3	26.5 x 18.5
EDG building no.3	14.3	26.5 x 18.5
Swing generator building	14.3	26.5 x 18.5

7.7.2.6 Background Concentrations

Both the D1 and H1 calculations require background pollutant concentrations; for D1 these are specified as the 98^{th} percentile of hourly concentrations over a calendar year, while for H1 they are the annual averages.

Background concentrations of air pollutants for inclusion in the D1 and H1 calculations were taken from the Welsh air quality website [Ref-64] for a recent year, for a suitable continuous monitoring station representative of a rural location near the Welsh coastline. The selected site at Narberth covers all pollutants of interest with the exception of carbon monoxide.

The 98^{th} percentile pollutant concentrations and annual averages for the year 2014 for Narberth (which recorded over 90% data capture) are presented in Table 7.7-5 for the relevant pollutants.

Carbon monoxide is measured at very few sites therefore a conservative value from the D1 guidance, 500 µg/m^3, as the 98th percentile has been applied in the assessment. The 2014 measured annual average value for Port Talbot of 200 µg/m^3 is used in H1.

Table 7.7-5: Background Pollutant Concentrations 2014 (µg/m^3)

Pollutant	98th Percentile of Hourly Means	Annual mean
Oxides of nitrogen	Not used	5.4
Nitrogen dioxide	22.0	3.8
Nitric oxide	5.0	Not used
Sulphur dioxide	6.0	2.3
Particulate matter	38.0	13.7

7.7.3 D1 Stack Height Determination

7.7.3.1 Engines

D1 stack height calculations were only undertaken for the EDG and BBG generators to inform the upper stack height boundary for the AERMOD screening assessment. The results of these calculations were 70 m for the EDGs and 62 m for the BBGs, above ground level.

The D1 assessment was not undertaken to support the H1 screening assessment. The H1 screening assessment was undertaken on the basis of the standby EDGs and BBGs discharging through a stack which will discharge at a height of three metres above the level of the roof. It is noted that this approach is in line with the D1 assessment guidance Section 6.2 “Overriding minimum requirements for discharge stack heights”.

7.7.3.2 Boilers

The auxiliary boilers will discharge via a single, combined flue stack of 1.5 metres diameter. The assessment for the auxiliary boilers is based the assumption that pollutants will be emitted at the EPR1.01 benchmarks (with the exception of sulphur, based on fuel mass flow), in order to determine suitable emission rates in the absence of a detailed design.

The auxiliary boilers will be fitted with a stack which will discharge at a height of 20 metres above ground level; this meets the D1 Section 6.2 “Overriding minimum requirements for discharge stack heights”. A D1 assessment is therefore not presented for the auxiliary boilers.

7.7.4 H1 Screening Assessment

7.7.4.1 H1 methodology

A screening assessment of the combustion equipment stack emissions was carried out using the approach described in Annex F of the H1 Guidance Document [Ref-65]. The screening assessment is very conservative and allows the user to determine whether or not a further, more detailed assessment of emissions to air is likely to be required or whether the emissions to air can be screened out as being insignificant.

The methodology uses very conservative dispersion factors (units of µg/m^3/g/s) for a range of “effective stack heights”, which are then multiplied by a pollutant emission rate to estimate the “process contribution” (PC), i.e., the maximum ground level pollutant concentration. The PCs are then compared with short and long term air quality criteria (environmental assessment levels (EALs)) and a decision made on whether a further, more detailed assessment such as dispersion modelling is appropriate.

The effective height of release should, according to the guidance, be considered as zero where the point of discharge:

- is less than 3 m above the ground or building on which it is located; or,
- is greater than 3 m above the ground or building on which it is located but less than the height of any building within a distance 5L from the point of discharge (where L is the lesser of the building height and the maximum projected width between two points at the same height in the building). This criterion is based on the assumption that such releases may become entrained in the building wake cavity.

Where the height of the release is greater than 3 m above the ground or building on which it is located, but less than 2.5 times the height of the building the stack is positioned on, or the tallest adjacent building within 5L, the effective height of release can be estimated from:

$U_{eff} = 1.66*H [U_{act}/H - 1]$

Where:

- H is the height (m) of the tallest adjacent building within the distance 5L (where L is the lesser of the building height and the maximum projected width between two points at the same height in the building);
- Ueff is the effective stack height;
- Uact is the actual (physical) stack height.

Owing to ambiguity in the H1 guidance, it is not clear whether the distance 5L should relate to any building or the building upon which the stack is located. Furthermore, the precise location and dimensions of the HB/B are not yet known. Therefore, at this stage, the assessment for the engines (standby EDGs and BBGs) has assumed that the reactor building is the relevant building, while for the boiler it has been assumed to be the HB/B. This assessment is therefore indicative only and the results may be expected to change as the design evolves and a final site layout is developed.

Therefore, in the case of the standby EDGs and BBGs the effective stack height must be considered as zero, since the design release height of 3 metres above the roof is below the height of the nearby reactor building. For the boilers, the effective stack height is 8 m, on the basis of the actual stack height of 20 m (Section 7.7.3.2) and a height (H) value of 15 m.

The H1 dispersion factors, shown in Table 7.7-6, are derived from a mathematical dispersion model and are presented as maximum average ground level concentrations for unit mass emission rates, at different effective stack heights. Linear interpolation can be applied to derive dispersion factors for intermediate effective release heights.

Table 7.7-6: H1 Screening Assessment Dispersion Factors

Effective height of release (m)	Dispersion Factor (µg/m^3/g/s)	
	long term (annual)	short term (hourly/daily)
0	148	3,900
10	32	580
20	4.6	161
30	1.7	77
50	0.52	31
70	0.24	16

A summary of the H1 effective release heights and associated dispersion factors for the engines and boilers is presented in Table 7.7-7. It should be noted that these dispersion factors assume “worst case” conditions since they make no allowance for thermal or momentum plume rise. The calculated PCs are therefore very likely to be a significant overestimate of the ground level concentrations that will, in reality, occur. Such an assumption is particularly unrealistic for the engines, given an exhaust temperature in the order of 400 °C and exit velocity of 20 m/s. Furthermore, the results are the maximum concentrations expected to occur anywhere and hence are not necessarily representative of the concentrations at the closest sensitive receptors beyond the site boundary of a facility in its eventual setting.

Table 7.7-7: H1 Effective Release Height Calculations

Stack	Uact	H	Ueff	Dispersion Factor (µg/m^3/g/s)	
				long term	short term
EDG	17.3	42.3	0	148	3,900
BBG	17.3	42.3	0	148	3,900
Boiler	20	15	8	55.2	1,244

When applying the relevant dispersion factor to the pollutant emission rate to calculate the PC, the H1 screening methodology assumes a continuous release at that emission rate. In view of the fact that the combustion engines under consideration for the UK ABWR are for emergency/standby use only, it would be inappropriate to use the same emission rate for the long and short-term assessments. To derive a more realistic long-term emission rate, a factor of 20/8,760 has been applied to the long-term PC, based on the likely number of hours’ operation across the course of the year for the EDGs and BBGs.

At least one boiler will be operational during most circumstances. For the purposes of the H1 screening assessment for long and short-term operation, both the boilers are conservatively assumed to be in operation 100% of the time. For routine operations, it is expected that both boilers will be required to operate at up to full load during the winter, whereas for summer loading one boiler operating at 50% nominal will suffice.

Any requirement for further work can be screened out for a pollutant where the long-term PC is less than 1% of the EAL *and* the short-term PC is less than 10% of the relevant EAL. If the PC cannot be screened out on this basis, it is necessary to calculate the total “predicted environmental concentration” (PEC) including the background component. For those pollutants for which the PC is not screened out, H1 guidance further advises that detailed modelling may be useful where there are relevant sensitive receptors, and/or the long-term PEC is greater than 70% of the EAL and/or the short-term PC is greater than 20% of the relevant EAL minus twice the annual mean background concentration.

For the screening assessment presented in this document, the long-term PCs have been added on to the annual average background concentration measured at the Narberth air quality monitoring station in 2014. For the calculation of short-term PEC, H1 guidance advises that the long-term (annual average) background concentration be doubled and added to the short-term PC.

7.7.4.2 H1 Results

The results of the H1 screening assessment for human health are presented in Table 7.7-8. Estimated ground level concentrations (PCs) have been compared against the EALs set out in Annex F of the H1 guidance.

Table 7.7-8: H1 Results – Human Health Assessment

Pollutant	Period	EAL µg/m^3	PC µg/m^3	PC/EAL %	Back-ground µg/m^3	PEC µg/m^3	PEC/EAL %	Further work
Standby EDG (single flue)^								
*NO_2	Long-term	40	6.1	15	3.8	9.9	25	NO
	Short-term	200	35,326	17,663	7.6	35,334	17,667	YES
SO_2	Long-term	50	<0.01	0.01	-	-	-	NO
	Short-term	350	32	9.2	4.52	37	10	NO
CO	Short-term	10,000	6,318	63	400	6,718	67	YES
PM_{10}	Long-term	40	0.09	0.2	-	-	-	NO
	Short-term	50	1,014	2,028	27.3	1,041	2,083	YES
Backup Building Generator (single flue)^								
*NO_2	Long-term	40	4.0	10	3.8	7.8	20	NO
	Short-term	200	23,041	11,520	7.6	23,048	11,524	YES
SO_2	Long-term	50	<0.01	<0.01	-	-	-	NO
	Short-term	350	11	3.2	4.5	16	4.5	NO
CO	Short-term	10,000	2,456	25	400	2,856	29	YES
PM_{10}	Long-term	40	0.01	0.04	-	-	-	NO
	Short-term	50	167	334	27.3	194	388	YES
Auxiliary Boilers (single flue)								
*NO_2	Long-term	40	157	392	3.8	160.8	402	YES
	Short-term	200	1,769	885	7.6	1,777	888	YES
SO_2	Long-term	50	1.59	3.2	-	-	-	YES
	Short-term	350	5.4	10.3	-	-	-	YES
CO	Short-term	10,000	2,527	25.3	-	-	-	YES

Pollutant	Period	EAL µg/m³	PC µg/m³	PC/EAL %	Back-ground µg/m³	PEC µg/m³	PEC/EAL %	Further work
PM_{10}	Long-term	40	11.2	28	13.7	24.9	62	NO
	Short-term	50	253	505	27.3	280	560	YES

* Estimated from NO_x using Environment Agency "worst case" conversion factors of 0.7 for long-term NO_2 and 0.35 for short-term NO_2
^ Long-term results factored by 20/8760, to reflect expected hours of operation per year.

The results in Table 7.7-8 show that none of the pollutants may be screened out for the auxiliary boilers on the basis of the PC alone, since *neither* the 1% of long-term EAL nor the 10% of short-term EAL threshold is met.

As would be expected based on the limited number of hours of operation per year, it is the short-term PECs which determine the findings for the engines, with all pollutants requiring further assessment. Only sulphur dioxide may be excluded at this stage since *neither* the 1% of long-term EAL nor the 10% of short-term EAL threshold is exceeded.

In reviewing the results presented in Table 7.7-8 it should be noted that the H1 screening assessment applies a very conservative methodology; in particular the assumption that the emission from the stack has no thermal momentum or buoyancy to assist the dispersion of the plume. The ground level concentrations reported here are therefore higher than would be expected in the actual release.

H1 Annex F also requires an assessment of the impact on ecological sites. In this case, concentrations of oxides of nitrogen and sulphur dioxide are the relevant pollutants for comparison with critical levels for the protection of vegetation: annual mean concentrations 30 µg/m³ and 20 µg/m³ respectively. For both engines, the emissions for both pollutants can be screened out (based on the results for a single flue) whereas for the boilers further assessment is required for oxides of nitrogen. The results are shown in Table 7.7-9.

Table 7.7-9: H1 Results – Ecological Assessment

Pollutant	Period	EAL, µg/m³	PC, µg/m³	PC/EAL, %	Back-ground, µg/m³	PEC, µg/m³	PEC/EAL, %	Further work?
Standby EDG (single flue)^								
*NO_2	Long-term	30	8.7	29	5.4	14.1	47	NO
SO_2	Long-term	20	<0.01	0.01	-	-	-	NO
Backup Building Generator (single flue)^								
*NO_2	Long-term	30	5.7	19	5.4	11.1	37	NO
SO_2	Long-term	20	<0.01	<0.01	-	-	-	NO
Auxiliary Boiler (twin flue)								
*NO_2	Long-term	30	224	748	5.4	230	765	YES
SO_2	Long-term	20	1.59	8.0	2.3	3.9	19	NO

^ Long-term results factored by 20/8,760 to reflect expected hours of operation per year.

7.7.4.3 H1 – Summary of Results

The conservative nature of the H1 screening tool, i.e. an assumption of no thermal momentum or buoyancy to assist plume dispersion, means that no pollutants can be entirely screened out at this stage. Further assessment would be required at the site-specific assessment stage for:

- EDGs – short-term nitrogen dioxide, carbon monoxide and PM_{10};
- Backup generators - short-term nitrogen dioxide, carbon monoxide and PM_{10};
- Boilers - short- and long term oxides of nitrogen and nitrogen dioxide, sulphur dioxide, carbon monoxide, and short-term PM_{10}.

The calculations reported in the tables above have been undertaken using typical manufacturers' data combined with assumptions made in the absence of a detailed design. As such they provide a useful preliminary assessment.

The recommendation from this H1 screening assessment is that further assessment by means of detailed atmospheric dispersion modelling should be undertaken for all pollutant emissions from the engines and boilers, due to potential exceedences of the health-based and ecological EALs.

At the site-specific stage the stack heights adopted for each item of combustion equipment will need to be the subject of a stack height sensitivity study. Such a study should demonstrate the suitability of the proposed stack height(s) in achieving acceptable ground level concentrations at sensitive receptor locations. This study includes consideration of the site-specific aspects of the site, particularly topography and weather conditions. As such it is outside the scope of the GDA process and has not been undertaken here.

7.7.5 Screening Assessment Using a Dispersion Model – AERMOD

The short term NO_x emission reported using the Environment Agency's approved H1 assessment methodology (Table 7.7-8) for the EDG and BBG generators is considered an anomalous value. A key reason for this is the inherent conservativeness of the H1 methodology with no consideration of thermal momentum or buoyancy to assist the dispersion of the plume.

To understand the effect of this conservativeness on the result reported in Table 7.7-8 for short term NO_x, a further screening assessment was undertaken using the atmospheric dispersion model AERMOD. The use of an atmospheric dispersion model enables plume buoyancy (thermal and momentum effects) to be taken into account, as well as a full range of wind conditions.

Further assessment was not undertaken for the other pollutants.

7.7.5.1 AERMOD Methodology

The screening assessment used the US EPA regulatory atmospheric dispersion model AERMOD, version 14134. This has evaluated 1^{st} high and 19^{th} high hourly oxides of nitrogen concentrations for the specified receptor grid and on the site boundary.

Seven stack heights were assessed for each of the EDG locations. The starting point was a stack height of 17.3 m above ground level, i.e. 3 m above the 14.3 m roof height of the EDG buildings. The maximum stack height assessed was that identified in the D1 assessment, i.e. 70 m above ground level (55.7 m above the roof height). Interim heights at 10 metre intervals from 20 m to 60 m were also assessed.

Eight stack heights were assessed for the BBGs starting from a stack release height of 26.2 m above ground level, i.e. 3 m above the 23.2 m roof height of the BBG building, up to a maximum identified from the D1 assessment of 62 m above ground level. Interim heights at 5 m intervals from 30 m to 50 m and 60 m were also assessed. A single BBG was modelled, for a stack located in the centre of the Back-up Building.

Terrain data were not included in the model, as the generic site is flat. The relevant buildings for the generic site layout were included in the model, as described in Section 7.7.2.5. Building downwash effects were calculated in AERMOD using the direction-specific parameters derived from the building profile input programme.

Ground level concentrations were modelled over a 2 km by 2 km Cartesian receptor grid, spaced at 100 m intervals centred on the Reactor Building

7.7.5.1.1 Meteorological Data

Hourly sequential meteorological data for Valley Meteorological station for the year 2014 were used in the screening modelling study. The meteorological data identified the prevailing wind as from the south and adjoining sectors to the south west. Winds from the west are also of above average frequency. There is a secondary prevailing wind from the east north east.

7.7.5.2 AERMOD Results

This section presents the maximum short term ground level concentrations of oxides of nitrogen for on-site receptors and the maxima at the site boundary for the EDGs and BB generators. The results have been assessed against the ambient air criterion for the protection of public health for nitrogen dioxide, as set in the national Air Quality Strategy. Nitrogen dioxide concentrations have been estimated from the oxides of nitrogen concentrations using the Environment Agency's "worst case" conversion factor of 0.35 for short-term concentrations. In light of the short travel distance between the source and the maximum ground level concentrations for some of the shorter stack heights considered, this may be conservative, however, it is an accepted approach for screening and thus is appropriate for this generic site assessment where several key parameters are yet to be determined.

It is noted that a simple comparison of a maximum modelled nitrogen dioxide concentration (i.e. the process contribution) against the Air Quality Strategy objective of 200 $\mu g/m^3$ (as presented at this screening stage), does not make allowance for ambient background concentrations, although it will be appreciated that this would not be possible or appropriate at this generic site assessment stage.

The Air Quality regulations describe certain objectives in terms of the number of exceedences of the prescribed standard (i.e. the relevant concentration for the protection of human health) that are allowed per year; 18 hours in the case of the nitrogen dioxide short-term objective. Such an allowance was made when setting objectives to allow for instance the influence of anomalous weather conditions that cause regional "pollution events".

The 19th highest hourly concentrations have been presented to reflect the "permitted" 18 exceedences per year at an ambient air quality monitoring station. Given the uncertainty inherent in the indicative parameters described, the tabulated results are reported to two significant figures only, as appropriate for a generic site screening study of this nature.

7.7.5.2.1 EDGs

The maximum or "1st high" hourly average ground level concentrations of oxides of nitrogen and nitrogen dioxide within the site, on the site boundary and across the entire modelled grid have been modelled separately for each of the three EDGs. The results are summarised in Table 7.7-10, Table 7.7-12, and Table 7.7-14 respectively for EDG1, EDG2 and EDG3

The "19th high" maximum hourly average ground level concentrations of oxides of nitrogen and nitrogen dioxide within the site, on the site boundary and across the entire modelled grid are summarised in Table 7.7-11, Table 7.7-13, and Table 7.7-15 for the engines EDG1, EDG2 and EDG3 respectively.

The 1st high hourly average concentrations are higher for EDG1 than for EDG2 and EDG3. The higher results are due to the less favourable position of the EDG1 building in relation to the other buildings and thus increased building downwash effects. The radioactive waste building is located to the north of the EDG1 stack and the reactor building is located to the east of the EDG1 stack, hence plume dispersion may be expected to be influenced to a greater extent by building downwash. Due to the location of EDG2 and EDG3, it is expected that plume dispersion will be less influenced by building downwash due to those structures.

Table 7.7-10: Maximum 1st High Hourly Average Concentrations for Various Stack Heights - EDG1

Stack height	Maximum on-site			Maximum on boundary			Grid Maximum		
	NO_x µg/m^3	NO_2 µg/m^3	PC / Criterion %	NO_x µg/m^3	NO_2 µg/m^3	PC / Criterion %	NO_x µg/m^3	NO_2 µg/m^3	PC / Criterion %
17.3	1,600	550	270	1,100	380	190	1,600	550	270
20	1,500	520	260	910	320	160	1,500	520	260
30	960	340	170	480	170	84	960	340	170
40	700	250	120	340	120	59	700	250	120
50	460	160	81	210	72	36	460	160	81
60	200	68	34	110	38	19	200	68	34
70	79	28	14	59	21	10	92	32	16*

** Maximum occurs off site*

Table 7.7-11: Maximum 19th High Hourly Average Concentrations for Various Stack Heights - EDG1

Stack height	Maximum on-site			Maximum on boundary			Grid Maximum		
	NO_x µg/m^3	NO_2 µg/m^3	PC / Criterion %	NO_x µg/m^3	NO_2 µg/m^3	PC / Criterion %	NO_x µg/m^3	NO_2 µg/m^3	PC / Criterion %
17.3	1,500	530	270	580	200	100	1,500	530	270
20	1,300	440	220	500	170	87	1,300	440	220
30	720	250	130	340	120	60	720	250	130
40	540	190	94	220	78	39	540	190	94
50	340	120	60	150	54	27	340	120	60
60	180	63	32	98	34	17	180	63	32
70	75	26	13	56	20	10	75	26	13

Table 7.7-12: Maximum 1st High Hourly Average Concentrations for Various Stack Heights - EDG2

Stack height	Maximum on-site			Maximum on boundary			Grid Maximum		
	NO_x µg/m^3	NO_2 µg/m^3	PC / Criterion %	NO_x µg/m^3	NO_2 µg/m^3	PC / Criterion %	NO_x µg/m^3	NO_2 µg/m^3	PC / Criterion %
17.3	1,400	470	240	990	350	170	1,400	470	240
20	1,300	440	220	870	300	150	1,300	440	220
30	680	240	120	530	190	93	680	240	120
40	350	120	60	310	110	54	350	120	62*
50	180	62	31	200	70	35	220	77	38*
60	98	34	17	120	43	21	140	50	25*
70	54	19	10	66	23	12	94	33	16*

** Maxima occur off site*

Table 7.7-13: Maximum 19th High Hourly Average Concentrations for Various Stack Heights - EDG2

Stack height	Maximum on-site			Maximum on boundary			Grid Maximum		
	NO_x µg/m^3	NO_2 µg/m^3	PC / Criterion %	NO_x µg/m^3	NO_2 µg/m^3	PC / Criterion %	NO_x µg/m^3	NO_2 µg/m^3	PC / Criterion %
17.3	1,200	410	200	650	230	110	1,200	410	200
20	1,000	350	180	560	200	98	1,000	350	180
30	560	200	98	360	120	62	560	200	98
40	310	110	54	230	80	40	310	110	54
50	150	52	26	150	54	27	160	55	27*
60	90	32	16	97	34	17	110	38	19*
70	50	18	9	53	19	9	76	27	13*

** Maxima occur off site*

Table 7.7-14: Maximum 1st High Hourly Average Concentrations for Various Stack Heights – EDG3

Stack height	Maximum on-site			Maximum on boundary			Grid Maximum		
	NO_x µg/m^3	NO_2 µg/m^3	PC / Criterion %	NO_x µg/m^3	NO_2 µg/m^3	PC / Criterion %	NO_x µg/m^3	NO_2 µg/m^3	PC / Criterion %
17.3	1,300	470	240	1,100	370	180	1,300	470	240
20	1,300	450	230	910	320	160	1,300	450	230
30	680	240	120	560	200	98	680	240	120
40	340	120	60	280	99	50	360	130	63*
50	150	53	26	180	62	31	220	77	38*
60	88	31	15	91	32	16	120	44	22*
70	51	18	8.9	54	19	9.4	75	26	13*

** Maxima occur off site*

Table 7.7-15: Maximum 19th High Hourly Average Concentrations for Various Stack Heights - EDG3

Stack height	Maximum on-site			Maximum on boundary			Grid Maximum		
	NO_x µg/m^3	NO_2 µg/m^3	PC / Criterion %	NO_x µg/m^3	NO_2 µg/m^3	PC / Criterion %	NO_x µg/m^3	NO_2 µg/m^3	PC / Criterion %
17.3	1,200	420	210	620	220	110	1,200	420	210
20	1,100	370	190	540	190	95	1,100	370	190
30	570	200	99	340	120	59	570	200	99
40	310	110	54	230	80	40	310	110	54
50	130	47	23	140	48	24	140	50	25*
60	82	29	14	85	30	15	93	33	16*
70	47	17	8.3	49	17	8.6	57	20	10*

** Maxima occur off site*

7.7.5.2.2 BBGs

The maximum 1st high hourly average and maximum 19th highest hourly concentrations are summarised in Table 7.7-16 and Table 7.7-17 for a BBG for oxides of nitrogen on-site, on the site boundary and field wide (only one set of results for BBGs presented as both generators are associated with the same building). As shown by the results, the maximum 1st high hourly average concentrations decrease with increasing stack height but to a much lesser degree above a 50 m stack height for both on-site concentrations and the maximum at the site boundary. The same pattern is observed for the maximum 19th high hourly concentration.

Table 7.7-16: BBG Maximum 1st High Hourly Average Concentrations for Various Stack Heights

Stack height	Maximum on-site			Maximum at boundary			Grid Maximum		
	NO_x µg/m^3	NO_2 µg/m^3	PC / Criterion %	NO_x µg/m^3	NO_2 µg/m^3	PC / Criterion %	NO_x µg/m^3	NO_2 µg/m^3	PC / Criterion %
26.2	490	170	86	350	120	61	490	170	86
30	390	140	68	300	110	53	390	140	68
35	260	91	45	240	85	42	260	91	45
40	180	63	32	180	63	32	180	63	32

Stack height	Maximum on-site			Maximum at boundary			Grid Maximum		
	NO_x µg/m³	NO_2 µg/m³	PC / Criterion %	NO_x µg/m³	NO_2 µg/m³	PC / Criterion %	NO_x µg/m³	NO_2 µg/m³	PC / Criterion %
45	91	32	16	91	32	16	91	32	16
50	42	15	7.4	43	15	7.6	55	19	9.5
60	23	8.0	4.0	25	8.7	4.3	34	12	5.9
62	21	7.2	3.6	23	8.2	4.1	32	11	5.7

Table 7.7-17: BBG Maximum 19th High Hourly Average Concentrations for Various Stack Heights

Stack height	Maximum on-site			Maximum at boundary			Grid Maximum		
	NO_x µg/m³	NO_2 µg/m³	PC / Criterion %	NO_x µg/m³	NO_2 µg/m³	PC / Criterion %	NO_x µg/m³	NO_2 µg/m³	PC / Criterion %
26.2	480	170	84	270	96	48	480	170	84
30	380	130	66	240	85	43	380	130	66
35	250	88	44	200	70	35	250	88	44
40	150	51	26	140	48	24	150	52	26
45	82	29	14	73	26	13	82	29	14
50	39	14	6.9	37	13	6.5	39	14	6.9
60	18	6.5	3.2	19	6.5	3.3	25	8.6	4.3
62	17	6.1	3	17	6.1	3.0	23	8.0	4.0

7.7.5.2.3 Summary of the AERMOD Assessment Results

The results of the AERMOD assessment undertaken are presented in Table 7.7-10 to Table 7.7-17. Two sets of results are presented, reporting the maximum short term ground level concentrations of oxides of nitrogen (NO_x and NO_2) for the EDGs and BBGs at different stack heights:

- Table 7.7-10, Table 7.7-12, Table 7.7-14, and Table 7.7-16 show the maximum 1st hourly short term ground level concentrations.
- Table 7.7-11, Table 7.7-13, Table 7.7-15, and Table 7.7-17 show the maximum 19th hourly short term ground level concentrations. The 19th hourly result addresses the allowance made in the Air Quality regulations for a number of exceedences of the prescribed objective that are permitted to occur in each year, namely 18 hours for the NO_2 short term objective. The results in Table 7.7-11, Table 7.7-13, Table 7.7-15, and Table 7.7-17 are therefore those assessed to occur in the first hour outside of the 99.79% compliance limit for the NO_2 short term objective (200 µg/m³), and represent the worst case at the objective compliance limit. Consequently the values presented in the tables are slightly lower than the equivalent values in Table 7.7-10, Table 7.7-12, Table 7.7-14, and Table 7.7-16.

The results show that for EDG1 (Table 7.7-10), a stack height of 20-30 m (from ground level) would result in a ground level concentration of NO_2 at the site boundary at a level equivalent to the EAL (200 $\mu g/m^3$). The 19th hourly result for EDG1 (Table 7.7-11) indicates that a smaller stack (between 17.3 m and 20 m from ground level) would achieve a similar result. The assessments of the other EDGs also show similar results. For the purposes of this assessment, compliance with the relevant EAL at the point where the general public could be exposed (the site boundary) is considered an appropriate demonstration that the potential impact from emissions to air from the combustion plant is acceptable.

Table 7.7-10 (EDG1) shows that a stack height of 20 m (above ground level) is assessed to result in a ground level NO_2 concentration above the EAL (PC value is 160% of the EAL), whereas a stack of 30 m in height is assessed to result in a ground level NO_2 concentration below the EAL (PC value is 84% of the EAL). The stack height that results in a PC value equivalent to the EAL is therefore somewhere between these two heights. The assessment of the other EDGs show a similar result. The results for EDG1 are slightly higher than the other two EDGs as a consequence of the less favourable position of the EDG1 building in relation to other buildings, resulting in increased building downwash effects (Section 7.7.5.2.1).

The assessment results for the BBGs (Table 7.7-16 and Table 7.7-17) show that a stack of 26.2m in height (above ground level) would result in a ground level concentration of NO_2 at the site boundary at a level below the EAL (PC value is 61% of the EAL), which is also considered acceptable. It is noted that a stack height of 26.2 m (above ground level) is the shortest overall stack height achievable whilst still allowing for a 3 m stack on top of the Backup Building (B/B). As with the EDGs the 19th hourly results are slightly lower.

7.7.6 Implications of the AERMOD Results to the H1 Results

As described in section 7.7.5, the AERMOD assessment was undertaken in order to understand the inherent conservatism of the H1 assessment methodology, by using an alternative methodology that enabled plume buoyancy (thermal and momentum effects) and a full range of wind conditions to be taken into account.

The H1 assessment was undertaken using a single stack height of 17.3 m (above ground level) for the EDGs, and 26.2 m (above ground level) for the BBGs. This height is equivalent to a 3 m stack on top of the EDG and B/B buildings respectively. Comparison of the results from the H1 assessment to that reported for the same stack height by the AERMOD assessment (maximum 1st hourly results)[13], show that the results reported by the AERMOD assessment are:

- For the EDGs – short term NO_2 value is 71 times smaller[14] than that reported by the H1 assessment (250% of the EAL compared with 17,663% of the EAL for the H1 assessment).
- For the BBGs – short term NO_2 value is 134 times smaller than that reported by the H1 assessment (86% of the EAL compared to 11,520% of the EAL for the H1 assessment).

The smaller NO_2 value reported by the AERMOD assessment for the same stack height illustrates the conservatism of the H1 assessment, in particular, the assumption in the H1 assessment that the emission from the stack has no thermal momentum or buoyancy to contribute to the dispersion of the plume. The requirement of the H1 assessment to assume a zero effective stack height for the EDGs and BBGs adds to the conservatism that is applied.

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[13] The maximum 1st hourly results from the AERMOD assessment have been used for the comparison exercise, rather than the 19th hourly results, because the other pollutants (such as PM_{10}) do not have the same compliance allowance in the Air Quality regulations. For example, for PM_{10} the allowance is for 35 exceedences per year. The 19th hour factor is therefore not appropriate for use in the comparison exercise.

[14] An average value of the maximum on-site 1st hourly AERMOD results for the EDGs was used to determine this value.

As described above, an objective of the AERMOD assessment undertaken was to understand the effects that the assumptions in the H1 assessment methodology had on the results reported in Table 7.7-8. As a consequence of this, the AERMOD assessment was undertaken only for the most significant value reported by the H1 assessment, namely the short term NO_2 emission. The scope of the AERMOD assessment was not intended to apply the methodology to all of the potential pollutants. Such an approach was considered beyond the requirements of the generic design assessment.

However, applying the level of reduction in the results reported by the AERMOD assessment (compared to those reported by the H1 assessment) to the other pollutants in Table 7.7-8 where the PC value is >100% (short term PM_{10} for the EDGs, BBGs and auxiliary boilers and short and long term NO_2 for the auxiliary boilers) indicates that with a more detailed assessment methodology, these results may also be expected to be reduced to an acceptable level. The short term PM_{10} values for the EDGs and BBGs could be expected to be reduced to 29% and 2% of the EAL respectively, for example. An evaluation of the potential effect on the PM_{10} and NO_2 emissions from the auxiliary boilers is less straightforward as an AERMOD assessment was not undertaken for the boilers. However, the basis for the reduction seen for the emissions for the EDGs and BBGs, for example, consideration of thermal buoyancy and plume momentum, also applies to the auxiliary boilers, although to a slightly lesser degree, owing to the lower flue gas temperature likely to be achieved by the boilers. Nevertheless, a reduction in the ground level PC values for the emissions from the auxiliary boilers should also be expected. It is noted that only a ten-fold reduction in the PC values reported in Table 7.7-8 for NO_2 and PM_{10} for the auxiliary boilers would reduce the respective PC values to <100% of their EAL. A similar scenario may also be expected for the results reported in Table 7.7-9 (Ecological Assessment). This would result in the PC values for all of the pollutants reported in this table (Table 7.7-9) being <100% of their respective EALs.

7.7.7 Operation of the Combustion Plant

The three EDGs are required to supply emergency electrical power to class A-1 safety rated equipment to allow safe shut-down of the reactor in the event of a Loss of Off-site Power (LOOP) or a Loss of Coolant Accident (LOCA) simultaneously with LOOP. The EDGs are therefore required to start up automatically and rapidly on receipt of a start-up signal in the event of a LOOP or LOCA.

The two BBGs supply emergency electrical power to class A-2 safety rated equipment. These systems also support the delivery of a secondary means of safety function. The BBGs are required to start up automatically and rapidly on receipt of a start-up signal of LOOP or the reactor water level. EDGs and BBGs are started up simultaneously in the above case.

Routine testing is expected to be conducted on one EDG or BBG at a time. The test programme is anticipated as monthly, at least a 1 hr run at maximum continuous rating (MCR) (typically 1 hr 5 mins).

The conservative worst case test programme in any one year would therefore be for all EDGs and BBGs to have their 18 month tests (the regular test) combined with all EDGs and BBGs having their monthly tests (the surveillance test), minus the one month when the surveillance test is replaced by the regular test. Routine testing will not involve the simultaneous operation of multiple EDGs or BBGs.

The two auxiliary boilers provide steam to the site during start-up, normal operation and shut-down. During start-up or shut down, the auxiliary boilers will deliver the steam demand normally supplied from other station steam systems. For routine operations, it is expected that during the winter, both boilers will be required to operate at up to full load whereas for summer loading, one boiler operating at 50% nominal will suffice. At least one boiler will therefore be operational during most circumstances.

7.7.8 Conclusion

This document presents the results from two screening assessments of the potential impacts to air from emissions from the combustion installation. Although the H1 screening assessment did not screen out all emissions for the EDGs and BBGs for short term impacts, nor all emissions for the auxiliary boilers for both long and short term impacts, it is anticipated that further detailed air quality dispersion modelling at the site-specific stage will show that significant impacts are nevertheless unlikely. The H1 assessment technique is highly conservative and ignores additional dispersion factors such as plume buoyancy and is therefore likely to deliver a significant over-estimate of the potential for impact. Further assessment of the short term NO_x emission using the AERMOD based assessment highlighted this over-estimate, and demonstrated that a significant short term impact from NO_x for the EDGs and BBGs was also unlikely.

The results of the AERMOD assessment undertaken show that for the EDGs, a stack height of 20-30 m (from ground level) would result in a ground level concentration of NO_2 at the site boundary at a level equivalent to the EAL (200 µg/m^3) which is considered to be an acceptable level for the purposes of GDA. For the BBGs, a stack of 26.2 m in height (above ground level) would result in a ground level concentration of NO_2 at the site boundary at a level below the EAL and is likewise considered to be acceptable for the purposes of GDA.

The differences in the results reported by the AERMOD assessment for short term NO_2 emissions from the EDGs and BBGs, compared to those reported by the H1 assessment, highlight the extremely conservative nature of the H1 assessment methodology. On this basis (described in more detail in section 7.7.6), all the pollutants modelled using the H1 assessment (reported in Table 7.7-8 and Table 7.7-9) are concluded as likely to report a PC value <100% of the respective EAL when subjected to more detailed modelling.

It is noted that a decision on the stack height required at an actual site would be made as part of the relevant site-specific assessment. This assessment would include detailed dispersion modelling accounting for site topography, final building layout, final commissioning and operating strategy for the combustion plant, background ambient concentrations and a full set of meteorological data (typically five years' worth from an appropriate nearby location). As a consequence of the more detailed assessment undertaken at the site-specific stage, the stack height selected for an actual site is likely to differ from the indicative heights presented at GDA stage.

It is also necessary to take into account the normal operating pattern of the EDGs and BBGs whereby they will each operate for 12 hours per year, on average. The H1 assessment assumes operation of the EDGs and BBGs simultaneously (the emergency scenario) which is expected to be an extremely rare event. Under normal circumstances (routine testing), it is expected that the generator sets will run independently with no multiple operation. It is therefore considered that the basis of the assessment is extremely conservative and is, in fact, delivering a substantial over-estimate of the likely impacts.

Whilst short term impacts are likely to be of greatest concern under the normal operating pattern, the routine testing programme mostly involves very short runs where any potential impacts which might occur will be both transient and extremely short-lived. Overall, it is therefore expected that planned operation of the emergency and back-up generators are unlikely to lead to any significant impacts.

7.8 Greenhouse Gas Emissions Monitoring

The proposed approach to monitoring greenhouse gas emissions will meet the requirements contained in : The Monitoring and Reporting Regulation - General guidance for installations (MRR No 1), which provides guidance on the implementation of Commission Regulation (EU) No. 601/2012. It is not proposed, however, that a detailed Monitoring Plan will be developed for GDA, as this is more appropriately developed by the operators of UK ABWRs.

The purpose of the Monitoring Plan is to ensure that systems are in place that allow the UK ABWR operator to comply with their obligations under the European Union Emissions Trading Scheme (EU ETS) as described in the EU Emissions Trading Directive 2003/87/EC and Commission Regulation (EU) No. 601/2012. The Monitoring Plan should enable data on the annual emissions from the UK ABWR site to be presented to an external verifier in a way that is clear and transparent. The monitoring methodology used should therefore be as simple as possible, drawing on reliable data sources, robust metering instruments, short data flows and effective control procedures.

7.8.1 Monitoring Approaches

The MRR No. 1 states that there are numerous monitoring methodologies available for the UK ABWR that can be put together using a building block type approach to form an overall monitoring system. There is an onus on the operator to demonstrate that these blocks have been put together in such a way that there are no gaps in the monitoring or any double counting of emissions. The approved monitoring methodologies are as follows:

- Calculation based approaches:
  - Standard methodology;
  - Mass balance.
- Measurement based approaches.
- Methodology not based on tiers ('fall-back approach').
- Combinations of approaches.

Calculation based approaches require a level of measurement to inform the calculations, typically in the form of fuel consumption quantity measurement. Measurement based approaches are based around direct measurement of the greenhouse gases themselves.

For the UK ABWR generic site it is proposed that an approach incorporating the 'Standard Methodology' is used as the primary monitoring approach (it is noted that the approach may change later in the design process). The basis of the 'Standard Methodology' is that the greenhouse gas emissions are calculated by measuring both the input fuels and process inputs, and then applying appropriate emission, process and oxidation factors to give the final total emissions.

The monitoring approach described will allow the UK ABWR to meet its requirements under the EU ETS, and for simple, clear and transparent data on the greenhouse gas emissions to be provided to the external verifier.

8. COMAH

8.1 Introduction

The purpose of this section, as determined at Step 1b stage, is to address the applicability of the Control of Major Accident Hazards (COMAH) Regulations (COMAH Regulations) to the UK ABWR generic design, and to confirm whether or not the UK ABWR is likely to require regulation under the COMAH Regulations[15].

The Step 1b submission described this process as being undertaken through two stages:

- Collection of data on materials stored at the UK ABWR site.
- Comparison of the quantities of COMAH-listed substances to be stored on a UK ABWR site with applicable COMAH qualifying thresholds (for named substances and generic risk-phrase groups and in aggregation).

To comply with the COMAH Regulations the comparison of the on-site inventory against the COMAH-listed thresholds should be made on the basis of the maximum possible inventories of materials on the generic site. This will decide if the site will be designated as a COMAH Upper Tier (UT), Lower Tier (LT) or non COMAH establishment.

In addition to the above, if the site is to be designated as COMAH UT or LT establishment then a Hazardous Substances Consent will be required.

The notification requirements to the regulators for COMAH UT and LT establishments are summarised within this section.

8.2 P&ID Requirements

The EA has identified the information they require to carry out the GDA in the P&ID [Ref-1]. The P&ID [Ref-1] requirement relating to COMAH legislation is reproduced below:

'Identify any need for on-site storage of substances above the qualifying thresholds in COMAH15.

If a threshold is exceeded, describe the measures taken in the design to prevent a major accident to the environment'.'

The assessment that has been undertaken is presented in four sections.

- **Introduction to COMAH** (Section 8.4) - presents an overview of the COMAH assessment process, and describes the approach at GDA as a consequence of the current information available for the UK ABWR generic design.
- **Chemical inventory -** summarises the chemical inventory likely to be held onsite [Ref-67].
- **Findings - COMAH assessment** (Section 8.6) - presents the results of the assessment undertaken for GDA, and comments on the significance of the chemicals likely to be present in relation to the COMAH assessment.

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15 The assessment presented in this report has been made against the updated COMAH Regulations which came into effect in the UK on the 1st June 2015 [Ref-65]. These regulations implement EU Directive 2012/18/EU (also referred to as the Seveso III Directive). These regulations replace the COMAH Regulations that were in place at the start of the GDA process for the UK ABWR.

- **COMAH regulation requirements** (Section 8.7) - provides information on the further actions that would be required if the UK ABWR was subject to the COMAH regulations as a LT or UT establishment.

8.3 Regulatory Context

The COMAH Regulations 2015 [Ref-66] apply to establishments which store and process listed substances in quantities exceeding identified thresholds. The COMAH Regulations specify two threshold quantities for each listed substance or risk category of substance: the lower quantities are the threshold for LT COMAH establishments, the higher quantity is the threshold for UT COMAH establishments. The COMAH Regulations do not cover radioactive materials.

Operators of establishments covered by the COMAH Regulations have a general duty to take all necessary measures to prevent major accidents and to limit their consequences, and report any major accidents to the competent authority. They must prepare a 'Major Accident Prevention Policy' which should demonstrate that an adequate safety management system is in place to prevent major accidents. The enforcing authority should be sent details ('notification') of the name and address of the operator, the address of the establishment, identify who is in charge, and details and amounts of dangerous substances held at the establishment. Any changes in these details should be notified to the authority. If the site is an upper tier establishment additional requirements apply.

8.4 Background to COMAH

The COMAH regulations relate to the prevention, control and mitigation of the effects of accidents involving dangerous substances.

Schedule 1 of the regulations provides details of dangerous substances to which the regulations apply. Schedule 1 (Part 2) provides a list of named substances which are known to be particularly harmful to the environment and/or human health. Schedule 1 (Part 1) provides a list of categories of substances of similar hazardous properties which are not specifically named under Part 2. The categories and associated thresholds are presented in Table 8.4-1. The named substances listed under COMAH and their associated thresholds that are relevant to the UK ABWR site (i.e., those listed in [Ref-67]) are presented in Table 8.4-2. Schedule 1 (Part 3) details the notes referenced in Part 1 and Part 2. The notes referred to in Table 8.4-1 are detailed at the end of the table. The COMAH Regulations include specified quantitative thresholds of dangerous substances which are used to determine whether an establishment falls within LT (Column 2 in Table 8.4-1) or UT (Column 3) thresholds. These thresholds vary for different substances.

- If the site stores, uses or can produce more than the lower threshold for a dangerous substance but less than the UT threshold the site is classed as a LT establishment.
- If the site stores, uses or can produce more than the higher threshold the site is a UT establishment.

Table 8.4-1: Schedule 1 PART 1 Categories of Substances and Preparations not named specifically in PART 2

Column 1	Column 2	Column 3
Hazard categories in accordance with the CLP Regulation	**Qualifying quantity in tonnes of dangerous substances for the application of:**	
	Lower tier requirements	**Upper tier requirements**
Section 'H' – HEALTH HAZARDS		
H1 ACUTE TOXIC Category 1, all exposure routes	5	20
H2 ACUTE TOXIC Category 2, all exposure routes Category 3, inhalation exposure route (see note 7)	50	200
H3 SPECIFIC TARGET ORGAN TOXICITY (STOT) – SINGLE EXPOSURE STOT SE Category 1	50	200
Section 'P' – PHYSICAL HAZARDS		
P1a EXPLOSIVES (see note 8) Unstable explosives or Explosives, Division 1.1, 1.2, 1.3, 1.5 or 1.6, or Substances or mixtures which have explosive properties according to method A.14 of Regulation (EC) No. 440/2008 of 30 May 2008 laying down test methods pursuant to Regulation (EC) No. 1907/2006 of the European Parliament and of the Council on the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) (see note 9) and do not belong to the hazard classes Organic peroxides or Self-reactive substances and mixtures.	10	50
P1b EXPLOSIVES (see note 8) Explosives, Division 1.4 (see note 10)	50	200
P2 FLAMMABLE GASES Flammable gases, Category 1 or 2	10	50

Column 1	Column 2	Column 3
P3a FLAMMABLE AEROSOLS (see note 11(1)) ‘Flammable’ aerosols Category 1 or 2, containing flammable gases Category 1 or 2 or flammable liquids Category 1	150 (net)	500 (net)
P3b FLAMMABLE AEROSOLS (see note 11(1)) ‘Flammable’ aerosols Category 1 or 2, not containing flammable gases Category 1 or 2 nor flammable liquids category 1 (see note 11(2))	5,000 (net)	50,000 (net)
P4 OXIDISING GASES Oxidising gases, Category 1	50	200
P5a FLAMMABLE LIQUIDS Flammable liquids, Category 1, or Flammable liquids Category 2 or 3 maintained at a temperature above their boiling point, or Other liquids with a flash point ≤ 60°C, maintained at a temperature above their boiling point (see note 12)	10	50
P5b FLAMMABLE LIQUIDS Flammable liquids Category 2 or 3 where particular processing conditions, such as high pressure or high temperature, may create major accident hazards, or Other liquids with a flash point ≤ 60°C where particular processing conditions, such as high pressure or high temperature, may create major accident hazards (see note 12)	50	200
P5c FLAMMABLE LIQUIDS Flammable liquids, Categories 2 or 3 not covered by P5a and P5b	5,000	50,000
P6a SELF-REACTIVE SUBSTANCES AND MIXTURES and ORGANIC PEROXIDES Self-reactive substances and mixtures, Type A or B or organic peroxides, Type A or B	10	50
P6b SELF-REACTIVE SUBSTANCES AND MIXTURES and ORGANIC PEROXIDES Self-reactive substances and mixtures, Type C, D, E or F or organic peroxides, Type C, D, E, or F	50	200
P7 PYROPHORIC LIQUIDS AND SOLIDS Pyrophoric liquids, Category 1 Pyrophoric solids, Category 1	50	200

Column 1	Column 2	Column 3
P8 OXIDISING LIQUIDS AND SOLIDS Oxidising Liquids, Category 1, 2 or 3, or Oxidising Solids, Category 1, 2 or 3	50	200
Section 'E' – ENVIRONMENTAL HAZARDS		
E1 Hazardous to the Aquatic Environment in Category Acute 1 or Chronic 1	100	200
E2 Hazardous to the Aquatic Environment in Category Chronic 2	200	500
Section 'O' – OTHER HAZARDS		
O1 Substances or mixtures with hazard statement EUH014	100	500
O2 Substances and mixtures which in contact with water emit flammable gases, Category 1	100	500
O3 Substances or mixtures with hazard statement EUH029	50	200

Notes to the table:

Note 7. Dangerous substances that fall within Acute Toxic Category 3 via the oral route (H 301) fall under entry H2 ACUTE TOXIC in those cases where neither acute inhalation toxicity classification nor acute dermal toxicity classification can be derived, for example due to lack of conclusive inhalation and dermal toxicity data.

Note 8. The hazard class Explosives includes explosive articles (see Section 2.1 of Annex I to the CLP Regulation). If the quantity of the explosive substance or mixture contained in the article is known, that quantity must be considered for the purposes of these Regulations. If the quantity of the explosive substance or mixture contained in the article is not known, then, for the purposes of these Regulations, the whole article must be treated as explosive.

Note 9. Testing for explosive properties of substances and mixtures is only necessary if the screening procedure according to Appendix 6, Part 3 of the UN Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria ('the UN Manual of Tests and Criteria')(1) identifies the substance or mixture as potentially having explosive properties.

Note 10. If Explosives of Division 1.4 are unpacked or repacked, they must be assigned to the entry P1a, unless the hazard is shown to still correspond to Division 1.4, in accordance with the CLP Regulation.

Note 11(1). Flammable aerosols are classified in accordance with Council Directive 75/324/EEC of 20 May 1975 on the approximation of the laws of the Member States relating to aerosol dispensers(2). 'Extremely Flammable' and 'Flammable' aerosols of that Directive correspond to Flammable Aerosols Category 1 and 2 respectively of the CLP Regulation.

Note 11(2). In order to use this entry, it must be documented that the aerosol dispenser does not contain Flammable Gas Category 1 or 2 nor Flammable Liquid Category 1.

Note 12. According to paragraph 2.6.4.5 in Annex I to the CLP Regulation, liquids with a flash point of more than 35°C need not be classified in Category 3 if negative results have been obtained in the sustained combustibility test L.2, Part III, section 32 of the UN Manual of Tests and Criteria. This is however not valid under elevated conditions such as high temperature or pressure, and therefore such liquids are included in this entry.

Table 8.4-2: Schedule 1 PART 2 Named Dangerous Substances Relevant to the UK ABWR Generic Site

Column 1	**CAS number**	**Column 2**	**Column 3**
Dangerous substance		**Qualifying quantity in tonnes of dangerous substances for the application of:**	
		Lower tier requirements	**Upper tier requirements**
Acetylene	74-86-2	5	50
The following **CARCINOGENS** or the mixtures containing the following carcinogens at concentrations above 5% by weight: 4-Aminobiphenyl and/or its salts, Benzotrichloride, Benzidine and/or salts, Bis (chloromethyl) ether, Chloromethyl methyl ether, 1,2-Dibromoethane, Diethyl sulphate, Dimethyl sulphate, Dimethylcarbamoyl chloride, 1,2-Dibromo-3-chloropropane, 1,2-Dimethylhydrazine, Dimethylnitrosamine, Hexamethylphosphoric triamide, **Hydrazine**, 2-Naphthylamine and/or salts, 4-Nitrodiphenyl, and 1,3 Propanesultone	-	0.5	2
Hydrogen	1333-74-0	5	50
Mixtures of **sodium hypochlorite** classified as Aquatic Acute Category 1 [H400] containing less than 5% active chlorine and not classified under any of the other hazard categories in Part 1 of this Schedule, provided that the mixture in the absence of sodium hypochlorite would not be classified as Aquatic Acute Category 1 [H400].	-	200	500
Oxygen	7782-44-7	200	2,000

Column 1	CAS number	Column 2	Column 3
Petroleum products and alternative fuels (a) gasolines and naphthas, (b) kerosenes (including jet fuels), (c) gas oils (including **diesel fuels**, home heating oils and gas oil blending streams), (d) heavy fuel oils, (e) alternative fuels serving the same purposes and with similar properties as regards flammability and environmental hazards as the products referred to in points (a) to (d)	-	2,500	25,000

8.4.1 Standard COMAH Assessment Process

The standard process used to determine whether a site is subject to the COMAH regulations and classed as either UT or LT is as follows:

The process follows COMAH guidance document L111 [Ref-68]:

- Collate an inventory of chemicals and review the hazard rating or ratings that apply to each chemical. List the chemicals present by hazard rating and total amount in tonnes.
- Compare the amount of a dangerous substance with the total amounts against the LT and UT thresholds defined within Schedule 1 (Part 1) and Schedule 1 (Part 2) of the COMAH regulations. Chemicals are assigned to the COMAH categories according to their hazard rating.
    - Substances and mixtures are classified in accordance with the CLP Regulation[16] (Note 1 to Schedule 1 (Parts 1 and 2)).
    - Mixtures must be treated in the same way as pure substances provided they remain within concentration limits set according to their properties under the CLP Regulation, unless a percentage composition or other description is specifically given (Note 2 to Schedule 1 (Parts 1 and 2)).
    - For substances present which are not covered by the CLP Regulation (including waste), these are assigned to the most analogous category or named dangerous substance falling within the scope of the regulations (Note 5 to Schedule 1 (Parts 1 and 2)).
    - Where a substance may be assigned to more than one category, then the chemical is assigned to the category with the lowest threshold (Note 6 to Schedule 1 (Parts 1 and 2)). However Regulation 2(6) notes that where a substance is listed as a named dangerous substance (i.e. listed in column 1 of Part 2 of Schedule 1 (as shown in Table 8.4-2)) is also covered by a category in column 1 of Part 1 of that Schedule (as shown in Table 8.4-1), then the quantities that apply to the named substance (set out in columns 2 and 3 of Part 2 (shown in Table 8.4-2)) must be used. The quantities considered at those present at the generic site at any one time. There is no minimum time limit under which chemicals do not need to be considered[17].
- The threshold amount in tonnes reflects the total amount that the operator is allowed before the relevant COMAH tier is applied.
- If the quantity of dangerous substance onsite does not meet the lower threshold the site is not classed as a COMAH establishment.
- If the site uses, stores or can produce more than the LT threshold, the site is classed as a LT COMAH establishment.
- If the site uses stores or can produce more than the UT threshold, the site is classed as a UT COMAH establishment.

If the total amount of a named substance (Schedule 1 Part 2) or a category of substances (Schedule 1 Part 1) does not meet the threshold for LT, an aggregation process is applied. This is expanded upon in section 8.6.1.

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[16] European Regulation (EC) No 1272/2008 on classification, labelling and packaging of substances and mixtures. Referred to as the 'CLP Regulation' or 'CLP'.

[17] Confirmed by the EA to Hitachi-GE (February 2015)

8.5 Chemical Inventory

Information on the chemical inventory and the quantity of each chemical present is provided in separate document [Ref-67]. Table 8.5-1 lists the chemicals in the inventory to which the COMAH Regulations apply, on the basis that they are within one of the categories in Schedule 1 (Part 1) or a named substance (Schedule 1, Part 2). Where a substance may be assigned to more than one category, then the chemical is assigned to the category with the lowest threshold (Note 6 of Schedule 1 (Parts 1 and 2)) (Section 8.4.1).

Table 8.5-1 has been sub-divided into those chemicals used in operation, and those used only during commissioning, or decommissioning. The relevant COMAH thresholds are also presented for LT and UT establishments.

It is noted that the quantity of each chemical stored on the UK ABWR site has not been fixed at GDA stage, as the quantities of chemicals stored on site are typically operational decisions determined by the site operator at the site-specific stage, for example, decisions on whether to store bulk quantities of a chemical on site or receive regular deliveries of the chemical to the site, thereby reducing the storage requirement. It is therefore difficult to present at GDA the storage capacity for each chemical (in the chemical inventory) on the generic site. The following approach has therefore been used to determine the quantities of chemicals as presented in Table 8.5-1:

- Where the storage capacity of the primary containment vessel (tank or cylinder for example) identified as being used to store a chemical is fixed, then this has been used as the storage capacity for the COMAH assessment.
- Where the storage capacity of the primary containment vessel is not fixed, but the Safety Case sets a quantity of chemical to be stored on site, then the Safety Case based quantity has been used as the storage capacity for the COMAH assessment. It is noted at the site-specific stage that the quantity stored may be higher than this depending on operational decisions by the site operator.
- Where the storage capacity of the primary containment vessel is not fixed, and there is no specific Safety Case requirement, but information is available on the usage of the chemical (as determined by the operation of the UK ABWR), then seven days of supply for that chemical is assumed to be stored on site (at the usage rate identified) for the COMAH assessment. It is noted at the site-specific stage that the quantity stored may be lower or higher than this depending on operational decisions by the site operator.
- Where no information is available on quantities stored, and there is no Safety Case requirement or usage figure, then no assessment has been made at GDA regarding the relevance of the chemical to COMAH. It is expected that these chemicals will be addressed at the site-specific stage.

Table 8.5-1: Chemicals in the UK ABWR Chemical Inventory Relevant to the COMAH Regulations

Chemical	Quantity	Relevant to COMAH Regulations	COMAH Threshold (tonnes)	
			LT	UT
Chemicals stored on UK ABWR site for use in operation				
Acetylene (for cutting during construction and maintenance)	No information Not possible to determine the relevance of COMAH at GDA stage therefore.	Named substance	5	50
		P2 Physical hazard	10	50
	Threshold to be applied		5	50
Hydrogen		Named substance	5	50
		P2 Physical hazard	10	50
Cooling for generator in operation	18 Nm^3/day usage Therefore 11.33 kg for seven days supply[D].			
Injection into feedwater to reduce electrochemical corrosion potential in reactor	307 Nm^3/day (gas) usage Storage requirements not fixed at this stage. Estimated at 191 kg (assuming seven days supply[D]).			
	Threshold to be applied		5	50
Oxygen		Named substance	200	2,000
		P4 Physical hazard	50	200
Maintaining the oxide coating in the condensate system piping	160 l/h usage Not possible to determine the bulk storage requirement at GDA stage.			

Chemical	Quantity	Relevant to COMAH Regulations	COMAH Threshold (tonnes)	
			LT	UT
For recombining excess hydrogen during hydrogen injection	389 Nm^3/day (gas) (equivalent to 556 kg/day[E]) Based on Japanese ABWR, storage requirement is 20 m^3 (as liquid), equivalent to 22.8 tonnes[F].			
	Threshold to be applied		200	2,000
Diesel and light oil categorised as E2 environmental hazard				
Diesel - for diesel generators and boilers	2,863 m^3 for seven days supply[A] (2,419 tonnes)	E2 Environmental hazard	200	500
		Named substance (Petroleum product)	2,500	25,000
Light oil – for weekly maintenance during operation. Assumed to be diesel.	525 l (storage capacity) (0.44 tonnes)	E2 Environmental hazard	200	500
		Named substance (Petroleum product)	2,500	25,000
	Total 2,419.44 tonnes			
	Threshold to be applied[B]		2,500	25,000
Hydrazine (oxygen scavenger in auxiliary boiler system)	25 kg/y (usage in operation) (0.48 kg for seven days)	Named substance (Carcinogen)[C]	0.5	2
		E1 Environmental hazard	100	200
		H1 and H3 Health hazard	50	200
	Threshold to be applied		0.5	2

Chemical	Quantity	Relevant to COMAH Regulations	COMAH Threshold (tonnes)	
			LT	UT
Sodium nitrite (antirust agent for use in operation)	500 kg/y (usage in operation) (9.59 kg for seven days)	P4 Physical hazard	50	200
		H1 Health hazard	5	20
		E1 Environmental hazard	100	200
	Threshold to be applied		5	20
Ethylene glycol (to provide antifreeze function in operation)	1.2 m^3 (usage m^3/y) (0.023 m^3 (0.025 tonnes) for seven days)	H3 Health hazard	50	200
Lubrication oils (turbine lube oil and generator lube oil). These compounds have been categorised as category 3 chronic aquatic toxicants (hazard phrase H412). Consequently they are outside the COMAH Regulations.				
Chemicals stored on UK ABWR site for use at commissioning or decommissioning only				
Hydrazine (chemical decontamination during decommissioning)	3,200 l (storage capacity, comprising sixteen 200 l drum cans) (3.15 tonnes)	Named substance (Carcinogen)[C]	0.5	2
		E1 Environmental hazard	100	200
		H1 and H3 Health hazard	50	200
	Threshold to be applied		0.5	2
Sodium nitrite (antirust agent for use in operation)	1.1 tonnes (at initial operation)	P4 Physical hazard	50	200
		H1 Health hazard	5	20
		E1 Environmental hazard	100	200
	Threshold to be applied		5	20

[A] The value of 2,863 m^3 of diesel has been calculated as the quantity required to operate the three EDGs, the two BBGs, the two auxiliary boilers and the DAG for seven days, and therefore this is the quantity of diesel that is likely to be stored on site. Although the DAG is not designed to operate in addition to the EDGs, the COMAH Regulations apply to the storage rather than the usage of chemicals. The diesel required for the DAG is therefore included on the basis that this generator will have a separate fuel store to the EDGs.

[B] Diesel is listed within two COMAH categories, specifically as a named substance (Petroleum Product) and under the E2 Environmental Hazard category. Regulation 2(6) requires that where chemicals are listed as a named substance, then the threshold for named substance should apply. Therefore the diesel has been assessed against the named substance (Petroleum Product) threshold (2,500 tonnes LT, and 25,000 UT).

[C] The named substance categorisation for hydrazine only applies if the hydrazine is present at a concentration above 5% by weight. The storage concentration for hydrazine will be determined at the site-specific stage. Therefore, for GDA a concentration above 5% by weight has been assumed as a worst case (application of the lowest threshold).

[D] Quantity of hydrogen calculated on the basis that conditions at Nm^3 are $0^{\circ}C$ ($273^{\circ}K$) and 1.01325 bara as defined in EN ISO 13443:2005 and API Standard 2000. A density of 0.0899 kg/m^3 has been applied for hydrogen (http://www.engineeringtoolbox.com/gas-density-d_158.html, and also Table 9.12 of Hazardous Chemicals Handbook (2nd Edition) (2002).

[E] Quantity of oxygen usage per day calculated on the basis that conditions at Nm^3 are $0^{\circ}C$ ($273^{\circ}K$) and 1.01325 bara as defined in EN ISO 13443:2005 and API Standard 2000. An oxygen density of 1.429 kg/Nm^3 has been used to estimate the daily mass usage rate (as sourced from http://www.engineeringtoolbox.com/gas-density-d_158.html).

[F] The mass of oxygen storage has been calculated based on a conversion rate of 1 litre of liquid oxygen weighing 1.1417 kg (i.e. density of liquid O_2 is 1.1417 $tonnes/m^3$), as sources from (http://www.uigi.com/o2_conv.html).

8.6 Findings: COMAH Assessment

Assessment of the COMAH categorised chemicals (listed in Table 8.5-1) against the appropriate COMAH thresholds has identified that the COMAH thresholds are only exceeded at decommissioning stage for hydrazine (3.15 tonnes stored against the UT threshold of 2 tonnes, and assuming a concentration above 5% by weight).

On the basis of the information provided, COMAH thresholds are not exceeded for the UK ABWR in operation:

- The quantity of hydrazine required in operation (0.48 kg) is below the LT threshold.
- The quantity of diesel stored on site in operation has been calculated as 2,419 tonnes; as the quantity required to provide seven days of supply for the combustion plant, including the DAG. This is just below the LT threshold of 2,500 tonnes for this compound.

8.6.1 Aggregation Process

The aggregation process applies if the UT or LT thresholds are not equalled or exceeded for an individual dangerous substance. On the basis of the information provided in Section 8.6, the aggregation process applies for the UK ABWR generic site in operation.

The aggregation process is undertaken three times to assess the chemical inventory from the perspective of health hazards, physical hazards and environmental hazards:

- Health hazards - for the addition of dangerous substances listed in Part 2 that fall within acute toxicity category 1, 2 or 3 (inhalation route) or STOT SE category 1, together with dangerous substances falling within section H, entries H1 to H3 of Part 1;
- Physical hazards - for the addition of dangerous substances listed in Part 2 that are explosives, flammable gases, flammable aerosols, oxidising gases, flammable liquids, self-reactive substances and mixtures, organic peroxides, pyrophoric liquids and solids, oxidising liquids and solids, together with dangerous substances falling within section P, entries P1 to P8 of Part 1;
- Environmental hazards - for the addition of dangerous substances listed in Part 2 that fall within hazardous to the aquatic environment acute category 1, chronic category 1 or chronic category 2, together with dangerous substances falling within section E, entries E1 and E2 of Part 1.

Aggregation is applied first to determine whether the establishment is UT, using the following formula:

$q_1/Q_{U1} + q_2/Q_{U2} + q_3/Q_{U3} + q_4/Q_{U4} + q_5/Q_{U5} + \ldots$

- Where q_x = the quantity of dangerous substance x (or category of dangerous substances) falling within Part 1 or Part 2 of this Schedule, and Q_{UX} = the relevant qualifying quantity of dangerous substance or category x from Column 3 of Part 1 or from Column 3 of Part 2 of this Schedule.
- The establishment is UT if the sum for the health hazards, or the physical hazards, or the environmental hazards is equal to or greater than 1.

Aggregation is then applied to determine whether the establishment is LT. The same approach is applied, except that the quantities of dangerous substances are compared against their respective LT thresholds. The establishment is LT if the sum for the health hazards, or the physical hazards, or the environmental hazards is equal to or greater than 1.

The results of the aggregation calculations for the UK ABWR are presented in Section 8.6.1.1 (UT assessment) and Section 8.6.1.2 (LT assessment) below.

8.6.1.1 Aggregation Calculation (UT)

Aggregation calculations (Table 8.6-1) have been made to determine if the UK ABWR site in operation is an UT COMAH establishment. Aggregation calculations have not been made for the UK ABWR at decommissioning stage as the site is categorised as an UT establishment at this stage as a consequence of the 3.15 tonnes of hydrazine present.

Table 8.6-1: Aggregation Calculation to Determine if the UT Categorisation Applies for the UK ABWR in Operation

Chemical	Quantity (q_x)	UT threshold (tonnes) (Q_{ux})	Quotient value (q_x / Q_{ux})
Health category			
Sodium nitrite	9.59 kg	20	4.80×10^{-4}
Ethylene glycol	0.025 tonnes	200	1.25×10^{-4}
Hydrazine	0.48 kg	2	2.4×10^{-4}
	Total quotient value		8.45×10^{-4}
Physical category			
Hydrogen	11.33 + 191 = 202.33 kg	50	4.05×10^{-3}
Oxygen	22.8 tonnes[A]	2,000	1.14×10^{-2}
Acetylene	Information not available	50	Not calculated
Sodium nitrite	9.59 kg	200	4.8×10^{-5}
	Total quotient value		1.55×10^{-2}
Environmental category			
Diesel	2,419 tonnes	25,000	9.68×10^{-2}
Light oil	0.44 tonnes	25,000	1.76×10^{-5}
Sodium nitrite	9.59 kg	200	4.8×10^{-5}
Hydrazine	0.48 kg	2	2.4×10^{-4}
	Total quotient value		9.71×10^{-2}

[A] The mass of O_2 storage given is that required for recombining excess hydrogen during hydrogen injection. The storage requirement for maintaining the oxide coating in the condensate system piping has not been included as it is not possible to estimate this at the GDA stage.

As none of the three quotient values are equal to or greater than 1, then the UK ABWR site is not an UT COMAH establishment on the basis of aggregation.

8.6.1.2 Aggregation Calculation (LT)

Aggregation calculations (Table 8.6-2) have been made to determine if the UK ABWR site in operation is a LT COMAH establishment.

Table 8.6-2: Aggregation Calculation to Determine if the LT Categorisation Applies for the UK ABWR in Operation

Chemical	Quantity (q_x)	LT threshold (tonnes) (Q_{Lx})	Quotient value (q_x / Q_{Lx})
Health category			
Sodium nitrite	9.59 kg	5	$1.92\text{x}10^{-3}$
Ethylene glycol	0.025 tonnes	50	$5.00\text{x}10^{-4}$
Hydrazine	0.48 kg	0.5	$9.60\text{x}10^{-4}$
	Total quotient value		$3.38\text{x}10^{-3}$
Physical category			
Hydrogen	11.33 + 191 = 202.33 kg	5	$4.05\text{x}10^{-2}$
Oxygen	22.8 tonnes[A]	200	$1.14 \text{ x } 10^{-1}$
Acetylene	Information not available	5	Not calculated
Sodium nitrite	9.59 kg	50	$1.92\text{x}10^{-4}$
	Total quotient value		$1.55\text{x}10^{-1}$
Environmental category			
Diesel	2,419 tonnes	2,500	$9.68\text{x}10^{-1}$
Light oil	0.44 tonnes	2,500	$1.76/10^{-4}$
Sodium nitrite	9.59 kg	100	$9.59\text{x}10^{-5}$
Hydrazine	0.48 kg	0.5	$9.60\text{x}10^{-4}$
	Total quotient value		$9.69.\text{x}10^{-1}$

[A] The mass of O_2 storage given is that required for recombining excess hydrogen during hydrogen injection. The storage requirement for maintaining the oxide coating in the condensate system piping has not been included as it is not possible to estimate this at the GDA stage.

As none of the three quotient values are equal to or greater than 1, then the UK ABWR site is not an LT COMAH establishment on the basis of aggregation.

8.7 Potential Measures to Prevent a Major Accident to the Environment

This section addresses the P&ID requirement (listed in Section 8.2) to describe the measures taken in the design to prevent a Major Accident to the Environment (MATTE). The only chemical identified as present at a quantity higher than its relevant COMAH categories is hydrazine during decommissioning.

It is noted that the quantity of diesel stored (2,419 tonnes) is very close to the COMAH LT threshold (2,500 tonnes). The measures proposed to prevent the diesel (and light oil) causing a MATTE have therefore been included for completeness, as a small increase (96 m^3) in the quantity of diesel stored over the minimum quantity needed to meet the Safety Case requirement would exceed the LT threshold.

8.7.1 Diesel and Light Oils

The diesel and the light oils (which assumed to be physically and chemically equivalent to diesel) are expected to be present on the UK ABWR site in bulk storage tanks. The potential for these chemicals to cause a MATTE is primarily a consequence of their release into the environment in an unignited form, leading to the exposure of exposed soils (and potentially to underlying groundwater), or surface watercourses. Diesel may also cause a MATTE through its involvement in a fire, resulting in the generation of hydrocarbon contaminated firewater, the generation of thermal radiation and the formation of smoke and ash.

Prevention of a release of diesel into the environment, and the avoidance of a MATTE will be achieved through the generic site's Pollution Prevention Measures (PPM). The PPM are an integrated system comprising primary, secondary and tertiary physical containment measures along with the site's operational procedures and emergency response. The importance of site-specific issues, particularly topography and land availability, mean that the final design of the PPM system will be site-specific. However the following measures will be implemented, in line with regulatory requirements, and Competent Authority (CA) and regulator guidance [Ref-69][Ref-70][Ref-71][Ref-72][Ref-73][Ref-74].

8.7.1.1 Primary Containment

The primary containment is the equipment that has direct contact with the substance being stored, as well as the equipment that prevents the loss of primary containment under abnormal conditions, such as high-level alarms linked to shut down systems [Ref-69]. The primary containment bulk storage tanks for the diesel will meet the Oil Storage Regulations (2001) requirements[18] [Ref-70] of being of sufficient strength and structural integrity to ensure that in normal circumstances it is unlikely to leak or burst. The storage tanks will be appropriately labelled with the product type and tank capacity, and will be fitted with an appropriate means of measuring the quantity of oil present, an overfill alarm system, and a leak detection system compliant with standard BS EN 13160-1-2003[19].

The layout and design of the bulk oil storage facilities should limit the potential for an ignition event, and therefore a fire. Above ground pipework will be well supported, protected from corrosion and in a position where damage is minimised. Underground pipework will have no mechanical joints [Ref-70].

Fill points remote from the tank will be avoided where possible. Where remote fill points are used, the storage tank will be fitted with an automatic overfill prevention device [Ref-70].

[18] Apply to oil storage tanks of >200 litres capacity located above ground and outside buildings. Oil storage tanks within buildings will comply with fire safety aspects of Building Regulations.

[19] BS EN 13160-1-2003 specifies the general principles for leak detection systems for use with double-skin tanks, single-skin tanks and pipework designed for water polluting fluids.

8.7.1.2 Secondary Containment

Secondary containment is the system that minimises the consequences of a failure in the primary containment system by preventing the uncontrolled spread of the hazardous liquid. Secondary containment will be achieved by equipment that is external to and independent of the primary containment system [Ref-69], and have:

- A capacity greater than 110% of the tank rated capacity[20] of the largest tank or 25% of the tank rated capacity of the total tankage in the bund, whichever is the greater [Ref-70][Ref-71].
- Walls, joints and floor that are impervious to hydrocarbons and water [Ref-70], and resistant to fire [Ref-72]. The walls should be capable of withstanding the hydrostatic pressures that may occur as a consequence of the quantity released and the rate of release [Ref-75].
- No rainwater drain, or a rainwater drain that drains into a contained and enclosed system requiring positive action for operation. Similarly the secondary containment area shall have no pipework that penetrates through the bund floor or wall (so far as is reasonably practicable) [Ref-71][Ref-70].

Secondary containment areas will be constructed to the required standards, with new concrete bunds for example having complete engineered and reinforced concrete floors and walls designed and built to standard BS EN 1992-3-2006[21] [Ref-71].

Where bunds of earth construction are used, permeability levels will be in line with CA guidance (floor permeability should not be greater than the equivalent of a 1 m depth of soil with a permeability coefficient of 10^{-9} m/s, and achieved with an engineered solution rather than natural clay) [Ref-71], and CIRIA Guidance (C736) (maximum permeability of 10^{-9}m/s may be acceptable for earth bund walls and bund floors) [Ref-73].

Configuration of the secondary containment areas around the storage tanks will take account of HSE's guidance [Ref-74] that for tanks of up to 100 m^3 capacity the bund wall will be at least 1 m away from the nearest tank, and 2 m distance for larger tanks. This is to avoid releases of product from primary containment over the top of the bund through spigot flow (also known as jetting).

Allowance will be made for the containment of firewater and precipitation within the secondary containment area, in addition to the contents of the primary containment storage tank.

8.7.1.3 Tertiary Containment

Tertiary containment is the system that minimises the consequences of a failure in the primary and secondary containment systems by providing an additional barrier that is external to and independent of the primary and secondary containment systems to prevent the uncontrolled spread of hazardous liquid. It is identified by the COMAH CA [Ref-71] as good practice for installations in scope of the COMAH Regulations, and may comprise:

- Passive in-situ engineered measures such as tertiary containment bunds, lagoons and interceptors. These require no intervention in order to operate.
- Active measures such as pumps and remotely operated shut off valves (ROSOVs). These require some form of positive intervention (usually human action) in order to operate.

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[20] Tank rated capacity is the fill level in a storage tank which is far enough below the maximum capacity level to allow time to respond to final warning alarms and still prevent loss of containment/damage [Ref-72].

[21] BS EN 1992-3-2006 which specifies the design of concrete structures for the containment and retention of liquids.

Tertiary containment would be utilised when there is an event that causes the loss of containment (for example bund joint failure or firewater overflowing from a bund during a prolonged tank fire), and is intended to ensure that loss of control of hazardous materials does not result from such an event [Ref-68][Ref-72].

8.7.2 Hydrazine

Hydrazine has the potential to cause a MATTE as a consequence of its toxicity to biota. Appropriate primary, secondary and tertiary systems will be in place to ensure that exposure of the environment by hydrazine does not occur. Whilst the objective of the containment strategy will be the same as that for the bulk diesel stores, i.e. to prevent exposure to the environment, the much smaller quantity of hydrazine present on the UK ABWR generic site means that the scale of the containment measures applied will be different. The hydrazine is likely to be stored in drums or small containers. The measures implemented will meet the requirements of PPG26 [Ref-76]:

- Primary containment container has sufficient strength and structural integrity to contain the hydrazine and not burst or leak in normal circumstances. Stored inside a building where possible to provide protection against the weather.
- Containers stored within an appropriate secondary containment system that is impermeable to water and resistant to attack from the hydrazine. No drainage from the contained area.
- For a single or multiple drums, secondary containment would be provided by a drip tray with at least 25% of the volume of the drum. For single or multiple IBCs, drip trays will not be used, with the secondary containment sized to at least 110% of the container volume (for a single Intermediate Bulk Container (IBC)) and for multiple IBCs either 25% of the total volume of the containers or 110% of the largest container, whichever is the greater volume.

8.8 COMAH Regulation Requirements

The categorisation of a site as an UT or LT COMAH establishment entails a number of requirements for the site operator. Meeting these requirements is outside the scope of the P&ID requirements for COMAH at GDA. However, the requirements are included to highlight those that would apply at the site-specific stage if the COMAH Regulations also applied, and taking into account operational decisions made at the site-specific stage.

The following requirements apply:

- For both UT and LT establishments, operators must notify the CA[22] by providing the details listed in the following bullet points:
    - Name and address of the operator.
    - Address of the establishment concerned.
    - Name or position of the person in charge of the establishment.
    - Information sufficient to identify the dangerous substances or category of dangerous substances present.
    - The quantity and physical form of the dangerous substances present (or likely to be present).
    - A (brief) description of the activity or proposed activity of the installation concerned.

[22] The CA is the HSE and the EA. SEPA or Natural Resources Wales replace the Environment in Scotland and Wales respectively.

  - Details of the immediate environment liable to cause a major accident or to aggravate the consequences thereof.

- For LT establishments, operators must prepare a Major Accident Prevention Policy (MAPP). This duty reflects the role of management systems in accident prevention. The essential elements of a Safety Management System (SMS) which must be addressed by the MAPP are:
  - Company policy on major accidents.
  - Organisation and personnel (including training).
  - Identification and evaluation of major hazards.
  - Operational control.
  - Planning for emergencies.
  - Monitoring compliance, audit and review.
- Operators planning to build new UT establishments must submit information before construction. This is usually in the form of:
  - Pre-Construction Safety Report; and
  - Pre-Operations Safety Report.
- UT establishment operators do not have to prepare a separate MAPP document, but a full MAPP must be included within the COMAH Safety Report (the production and submission of which is a requirement for UT establishments). Pre-Construction and Pre-operations reports should be submitted to the CA in a reasonable timeframe before construction or on site operations commences. This is normally six months to one year before construction for the pre-construction report and a similar timeframe for the pre-operations report. It is normally the case that the CA will assess the report and feedback to the operator before the operator begins to build safety-critical parts of the establishment. This is to ensure that safety is considered fully at the design stage. It may be possible to combine the Pre-Construction and Pre-Operations Safety Report into one report; however, this must be discussed and agreed with the CA.
- Emergency Plans (onsite/offsite) must be prepared and discussed with CA before construction begins on site.
- Once the plant is fully operational the operator must submit a full COMAH safety report.

8.9 Additional Note: Hazardous Substances Consent

If at the site-specific stage the COMAH regulations apply and the site identified as a LT or UT establishment, then the site operator is also required to submit a COMAH Hazardous Substances Consent. The consent is a planning control that enables a Hazardous Substances Authority (HSA) to consider whether the presence of a significant quantity of a hazardous substance is appropriate having regard to the risk to the community[23].

This is required before site operations commence and although it is a separate regulatory process from COMAH, it is best undertaken in parallel to COMAH preparatory work. The hazardous substances consent process is outside the scope of the GDA process and would be addressed at the site-specific stage if required.

[23] Further information on this process is available at www.planningportal.gov.uk/permission/responsibilities/beforeyoustart/otherpermissions/hazsubs (England), http://wales.gov.uk/topics/planning/policy/dear-cpo-letters/hazsubletter/ (Wales), and www.scotland.gov.uk/Topics/Built-Environment/planning/publications/legislation (Scotland).

9. Fluorinated Greenhouse Gases and Ozone-Depleting Substances

9.1 P&ID Requirements

The P&ID requirement relating to fluorinated greenhouse gases and ozone-depleting substances is reproduced below:

> *'Identify whether any equipment included in the design will contain fluorinated greenhouse gases or ozone-depleting substances (as defined in EU, 2014 and EU, 2009, respectively). If so, describe the measures taken in the design to prevent and minimise leakage of such substances.'*

9.2 Use of fluorinated greenhouse gases and ozone-depleting substances in UK ABWR design

Any use of equipment which contains fluorinated greenhouse gases or ozone-depleting substances is not expected in the UK ABWR generic design and so no risk of release to environment is expected.

10. Conclusion

Conclusions are presented for each of the six sections addressed in this report.

It is important to note that much of the conventional environmental impact assessment work is heavily reliant on the site-specific data and so will necessarily fall out of the scope of the GDA assessment. Hitachi-GE is, however, committed to addressing as many requirements as possible in the design stage to mitigate effects where feasible. The assessments that are suitable for completion within GDA have been (and will be) undertaken at the appropriate stage. The results from these stages will be fed back into both the BAT assessments and the design process itself where appropriate, in order to ensure the design is fully optimised.

10.1 Conclusions - Water Use and Abstraction

The GDA is based on the assumption that the site is coastal with a once-through seawater cooling system. Information has been provided on the expected usage of seawater for this system. Alternative cooling water systems may be considered at the site-specific stage.

The GDA is based on the assumption that all freshwater requirements will be supplied by the local water company and that freshwater abstraction, and an abstraction license, will not be required. Alternative water supplies may be considered at the site-specific stage.

The selection and design of fish deterrent and / or return systems is dependent on a number of site-specific factors and will therefore be addressed at the site-specific stage.

10.2 Conclusions - Water Discharge

Discharge of water from the UK ABWR will occur from the cooling water systems (via the Seal Pit), the storm drain systems (SWSD and NSD) and from the LWMS. Releases will only occur if the discharge criteria are met. Draft criteria have been presented at GDA, derived from those in place at Japanese ABWR. Discharge criteria for UK ABWR will be developed at the site-specific stage to take into account site-specific parameters and further information on discharges to the sea.

Discharges from the Seal Pit will be seawater with primarily biocide and elevated levels of heat. The need for biocides and water treatment chemicals to control biofouling within the cooling water systems will be determined at the site-specific stage. At GDA stage sodium hypochlorite has been identified as a biocide that could be used, with a dosing strategy designed to result in a concentration of 0.1 mg/l TRO at the cooling water outfall.

Drainage from the storm drain systems (SWSD and NSD) and the LWMS have been characterised on the basis of the contaminants present, with the lowest levels and different categories of contaminants present in the SWSD drainage, and the highest in the HCW. Discharges from the LWMS are minimised through the overarching strategy of recirculating effluent through the treatment process to remove contaminants, and then re-using the treated effluent within the UK ABWR.

Assessment of the impact of chemicals in the liquid discharge has been undertaken for those chemicals expected to be present in the discharge from the cooling water outfall, namely ferrous ions, biocide (sodium hypochlorite), corrosion inhibitor (sodium nitrite), detergent, phosphate, ammonia and hydrazine. Generic impacts from these chemicals are expected to be low, as a consequence of the low concentrations present in the individual process effluent streams, coupled with the large dilution that will occur in the Seal Pit (with the cooling water discharge) prior to discharge to the sea. The actual impacts incurred will be depend on site specific factors, in particular the dispersion of the chemicals within the seawater. Conclusions - Options for the Beneficial Use of Waste Heat

Options for the use of the waste heat available from the ABWR have been reviewed. All of options reviewed have advantages and disadvantages, which result in some not being appropriate for use alongside the ABWR generic design. A key issue common to all options is the requirement for the user of the waste heat to be in close proximity to the ABWR. Health and safety issues may therefore be a limiting factor for all options. Options considered include:

- Crop growing - a possible option, although has a land take requirement adjacent to the ABWR.
- Aquaculture - a possible option, although the heat requirement would be small compared to that available from the power station.
- Under road heating - a possible option, although requires considerable infrastructure (piping) to be implemented, especially if retrofitted to existing roads. There also needs to be road network close to the ABWR requiring heating.
- De-icing at airports - not considered a possible option on safety grounds given the requirement for the ABWR and airport to be located close to each other.
- Algal growth - limited potential in the UK because of lower solar radiation levels in this country. Not considered as a possible option.
- Desalination - not considered as a possible option as the temperature of the waste heat from the ABWR is not high enough. Also has land take requirement close to the ABWR and the sea. Not really in demand in the UK for water supply.
- District heating - the waste heat from the ABWR is not of sufficient temperature for this system to be viable on its own. However, it may be a possible option using the WHEP approach, where the waste heat from the ABWR is used in conjunction with other systems to boost the temperature to a level sufficient for district heating use.

The ABWR is able to operate irrespective of any of the type of waste heat utilisation systems described in the bullet points above. However, the implementation of such a system would provide a sustainability benefit for the ABWR facility, as the waste heat generated is being put to further use rather than being disposed of.

Any option to use the waste heat depends on site-specific issues, such as land availability or building and infrastructure requiring heating. Further consideration of this will not be made until the site-specific stage.

10.3 Conclusions - Groundwater

The UK ABWR generic design does not include any intentional discharge to groundwater. Therefore the P&ID requirement for this aspect is considered complete and will not be addressed further in the GDA process.

10.4 Conclusions - Operation of Installation (Combustion Plant)

The following conclusions are summarised from the review of the combustion installation as described in this report for the UK ABWR GDA.

- The UK ABWR generic design does not include incineration activities. Therefore, regulatory requirements relating to incineration have not been addressed in the GDA process.
- Aggregate rated thermal input for the site exceeds 50 MW_{Th} (132.48 MW_{Th}).
- An Environmental Permit will be required at site permitting stage.
- The fuel to be used in the combustion installation is assumed to be UK specification ULSD.

10.4.1 Conclusions - Impact Assessment

The assessments undertaken show that for the EDGs, a stack height of 20-30m (from ground level) would result in a ground level concentration of NO_2 at the site boundary at a level equivalent to the EAL (200µg/m^3), and therefore at an acceptable level to people (receptors). For the BBGs, a stack of 26.2m in height (above ground level) would result in a ground level concentration of NO_2 at the site boundary at a level below the EAL, and therefore at an acceptable level to people (receptors). The assessment also concluded that these stack heights would result in acceptable ground level concentrations of the other pollutants modelled as part of the H1 assessment (SO_2, CO and PM_{10}), on the basis that the difference in the results reported by the AERMOD and H1 assessment for NO_2 also applied to the SO_2, CO and PM_{10} pollutants.

10.4.2 Conclusions - Greenhouse Gas Emissions Monitoring

For the UK ABWR it is proposed that an approach incorporating the 'Standard Methodology' is used as the primary monitoring approach (it is noted that the approach may change later in the design process). The basis of the 'Standard Methodology' is that the greenhouse gas emissions are calculated by measuring both the input fuels and process inputs, and then applying appropriate emission, process and oxidation factors to give the final total emissions.

The monitoring approach described will allow the UK ABWR to meet its requirements under the EU ETS, and for simple, clear and transparent data on the greenhouse gas emissions to be provided to the external verifier.

10.5 Conclusions - COMAH

The review of the chemical inventory for the UK ABWR generic site against the COMAH thresholds has identified that the UK ABWR generic site would be a lower tier COMAH establishment at decommissioning stage as a consequence of >0.5 tonnes of hydrazine being stored on the site at this stage. The UK ABWR generic site is also close to exceeding the lower tier threshold for petroleum products as a consequence of the quantity of diesel stored on site to meet the Safety Case requirement.

10.6 Conclusions - Fluorinated Greenhouse Gases and Ozone-Depleting Substances

Any equipment in the UK ABWR generic design does not contain fluorinated greenhouse gases or ozone-depleting substances. Therefore the P&ID requirement for this aspect is considered complete and will not be addressed further in the GDA process.