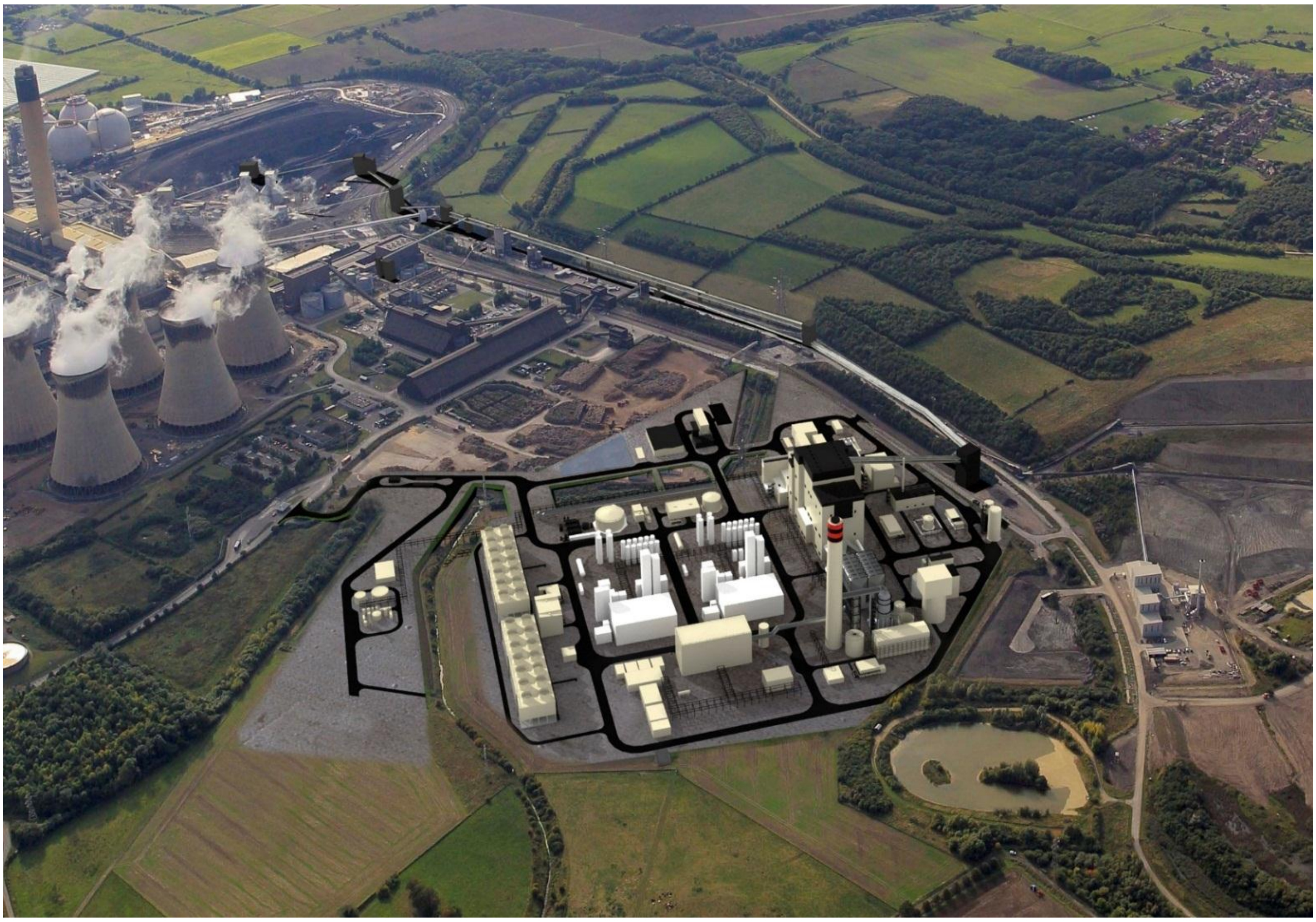
White Rose Carbon Capture and Storage (CCS) Project

Land Adjacent to and within the Drax Power Station site, Drax, near Selby, North Yorkshire

Environmental Permit
Chapter VIII – Point Source Emissions to Air



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Glossary

AOD	Above Ordinance Datum
ASU	Air Separation Unit
BS	British Standard
CCS	Carbon Capture and Storage
CEMP	Construction Environmental Management Plan
CPL	Capture Power Limited
dB	Decibel
EA	Environment Agency
EIA	Environmental Impact Assessment
EMS	Environmental Management System
EPC	Engineering, Procurement and Construction
ES	Environmental Statement
FGD	Flue Gas Desulphurisation
FRA	Flood Risk Assessment
GPU	Gas Processing Unit
HGV	Heavy Goods Vehicle
LWS	Local Wildlife Site
MWe	Megawatt
NERC	Natural Environment and Rural Communities (Act 2006)
NSIP	Nationally Significant Infrastructure Project
NYCC	North Yorkshire County Council
PEIR	Preliminary Environmental Information Report
SAC	Special Area of Conservation
SINC	Site of Importance for Nature Conservation
SPA	Special Protection Area
SSSI	Site of Special Scientific Interest
WHO	World Health Organisation
WSI	Written Scheme of Investigation

CONTENTS

1.0 INTRODUCTION

BACKGROUND TO WHITE ROSE CCS

Capture Power Ltd (CPL) plans to construct a new 448 MWe (gross output) ultra-super critical coal fired power station. The Project will have the capacity to provide electricity sufficient for 630,000 households whilst capturing two million tonnes of carbon dioxide (CO_2) per year arising from the combustion process (approximately 90% of CO_2 emissions generated by the plant). The generating station and the means to capture CO_2 together comprise the White Rose Carbon Capture and Storage (CCS) Plant.

The Project is a key part of the UK's development and commercialisation of CCS, which the Government is supporting through over £1billion of capital and research and development funding. Additionally, the Project will support the development of a CO_2 transmission pipeline (a separate project developed by National Grid Carbon Ltd (NGCL)) which it is hoped will, in the future, be used by other industries and power stations in the Yorkshire and Humber area to transport their CO_2 emissions for permanent storage in the North Sea in geological features.

The application site (henceforth the 'Project site') is located on land adjoining the existing Drax Power Station in North Yorkshire, England. CO_2 captured will not be stored on site as the Project will link to a CO_2 transport and storage solution as noted above. The Project is in line with Government strategies (for instance the CCS Roadmap (1)) for controlling the construction / operation of new electrical generation infrastructure whilst meeting carbon reduction targets for the energy sector in the UK.

A separate Development Consent Order has been submitted to The Planning Inspectorate and was 'Accepted for Examination' on 17 December 2015 but did not include application for a deemed Environmental Permit. Due to the proposed activities of White Rose Carbon Capture and Storage it has been agreed with the Environment Agency that the current Drax Power Limited Environment Permit (VP3530LS) can be varied to accommodate the operations of the White Rose Carbon Capture and Storage Plant.
This Environmental Permit application is made in order to make a variation to the existing Drax Power limited Environment Permit (VP3530LS). The application forms and the associated chapters form the application for a variation to the Environmental Permit which will seek to add the activities of the White Rose Carbon Capture and Storage project to the existing Drax Power Limited Environmental Permit.

2.0 DESCRIPTION OF THE PROCESS UNITS

In order to understand the emissions generated by the plant, a brief review of the technology proposed to be employed is required. The installation consists principally of Air Separation Units (2 trains), an ultra-supercritical boiler and flue gas abatement technology which also includes a Gas Processing Unit or GPU.

The Oxy Power Plant (OPP) is an ultra-supercritical boiler which means that the both the temperatures and pressures generated within the boiler exceed 600 degrees C and 265 bar. When considering the design of new, coal-fired power stations; supercritical or ultra-supercritical boilers are considered to be BAT due to the high efficiency which is associated with this technology. Currently there are no supercritical boilers operating within the UK.

AIR SEPARATION UNIT

Oxygen gas for consumption in the boiler plant, and nitrogen for use within the main air separation process itself, will be produced by a cryogenic distillation process. The ASU plant is centrally located within the main power plant site and is designed to be able to operate independently from OPP provided the utilities are available. Two trains will be present and are identical in specification and design. The ASUs are capable of generating gaseous oxygen for immediate use with the OPP or liquid oxygen for storage. This allows the Oxy Power Plant (OPP) to operate in oxy mode for a given amount of time should the ASUs not be operational, e.g. on a planned outage.

The ASUs operate and function via a series of compression and expansion of air resulting in the cryogenic separation of the major components of air, nitrogen and oxygen. Due to the nature of cooling and compression systems, there are a number of efficiency savings which can be realised and these are explored in Chapter 12.

Process description of ASU

Compression and pre-cooling Air for the process is filtered by a high efficiency filtration system and compressed to the required process pressure by a multistage, intercooled, electrically driven, turbo compressor. Compressed air from the compressor is then cooled by an after-cooler. The compressed air is cooled and washed in a direct contact air cooler in counter-flow orientation with water injected at two levels. Remaining contaminants such as water vapour, CO_2 and hydrocarbons in the air flow are absorbed while passing through an absorber vessel filled with molecular sieve material

Main heat exchanger

The main process air downstream of the molecular sieve station is then fed to the main heat exchanger. The primary purpose of this equipment is to cool the incoming air by transferring its heat to colder gas or liquid streams which are flowing from the main distillation system. The streams are physically separated from each other and it is only the heat that is exchanged. The main heat exchangers are located within the cold box.

Air Separation

In the distillation columns, contained within the cold boxes, the low pressure air is pre-separated into pure gaseous nitrogen at the top, and an oxygen enriched liquid at the bottom. The streams then exit via the main heat exchanger as described above.

Liquid Product Store

To meet the oxygen requirement of the OPP during periods when demand exceeds the ASU production, as well as during short duration shut downs of the ASU, a liquid storage back up system will be provided. Liquid oxygen drawn from the air separation plant will be stored in a vacuum insulated, horizontal pressure tank. Liquid pumps will be provided to feed liquid oxygen from this tank, either back into the ASU as liquid oxygen injection, or into the backup storage, which consist of 4 parallel connected vacuum insulated vertical pressure tanks. In case of a short term ASU shutdown, liquid oxygen from the backup storage can be vaporised in a steam heated water bath vaporiser and fed to the boiler.

Buffer Storage for Gaseous Product

Buffer storage vessels are fitted on the gaseous oxygen supply to the boiler in order to smooth out the pressure fluctuations and ensure oxygen supply pressure is maintained. The liquid oxygen backup system has an additional higher pressure buffer vessel in order to give a faster response time to provide instantaneous supply to the boiler.

OXYGEN FLOW TO THE OPP

The flow of oxygen gas to the oxy boiler is controlled by the supervisory control system. Each ASU train feeds into a common supply header at a constant pressure. If the pressure and or flow from the plants exceed the demand then the excess is vented back to the atmosphere until equilibrium is established. Similarly if the demand exceeds the instantaneous supply capability then there is a means to vaporize liquid oxygen to match the short term shortfall. This provides a high degree of control flexibility in operation.

ULTRA-SUPERCRITICAL BOILER

The boiler is a balanced draft, sliding pressure, supercritical, once through type boiler, utilizing a low NOx firing system. The boiler is capable of producing full load in either the air or oxy-fired mode of operation with a wide range of pulverised coals. The boiler provides steam (both high pressure and reheat pressure streams) to the steam turbine at the specified flow rate, temperature and pressure. The boiler is designed to burn coal and biomass delivered via Drax's existing coal yard. The boiler operates either in air mode (without CO2 capture) or in oxy mode (with CO2 capture). The air mode is primarily foreseen for start-up. In oxy-firing mode a high CO2 content flue gas stream is provided to the GPU. The GPU is used for further processing and compression in order to produce a relatively pure CO2 stream meeting the transport and storage specification. In air firing mode the flue gas generated is discharged to the atmosphere via the OPP main stack.

The fuel firing system consists of:

- four tangentially fired windboxes;
- the Separated Over Fire Air (SOFA) windboxes,
- the ignition system; and
- the scanners

The unique feature of tilting tangential nozzles allows for complete combustion of the fuel and for simple and reliable steam temperature control. In addition, the corner windbox firing method results in low NOx emissions with a variety of fuels, uniform furnace heat absorption patterns, and high boiler turndown capability. The low NOx Tangential Firing System (LNTFS) comprises two levels for over fire air. Both the fuel and air are directed towards the tangent of an imaginary circle in the centre of the furnace, thus, the name "Tangential Firing". A typical tangential firing flame pattern is generated through this firing pattern. During the operation, a horizontally swirling flame pattern is formed with a vortex in the centre of the furnace. This unique mixing technique forms a large single flame envelope, forcing the fuel and air from each corner to take the maximum path length through the furnace before it exits at the furnace outlet. Both in theory and in practice, any imbalance between windboxes is quickly "averaged out" within the horizontal flame pattern providing for strong mixing which does not depend on precision control of air and fuel admission assemblies.

The fuel and air/oxidant are introduced to the furnace through a device called a windbox assembly. The windbox is a vertical stack of alternating fuel and air/oxidant compartments with dampers associated with each compartment. One windbox is located in each of the four corners of the furnace. A typical tilting tangential windbox design is arranged vertically with alternating levels of air and fuel. The dampers at each compartment are controlled to vary the distribution of air/ oxidant over the height of the windbox, making it possible to change the velocities of the secondary air/ oxidant streams for ignition point adjustment.

3.0 FLUE GAS ABATEMENT TECHNOLOGY (FGD)

ELECTROSTATIC PRECIPITATORS

The Electrostatic Precipitator (ESP) is located between the Gas-Gas Heater (GGH) and the Induced Draft Fan (IDF) and removes the dust/fly ash released during the combustion process in the boiler. The flue gas is routed to the ESP through ductwork and an inlet nozzle. At the inlet of the ESP, gas distribution screens are provided to ensure uniform distribution of the flue gas over the entire cross section of the ESP to maximise removal efficiency.

While the dust loaded flue gas passes through the ESP, the dust is precipitated by charging the dust particles under the influence of a high voltage electric field created by the Transformer Rectifier sets. The collected dust is then rapped off from the electrodes through the rapping mechanism. The collecting plates are rapped periodically to dislodge the deposited dust to the hoppers below the ESP casing. The rapping system employs 'tumbling hammers', which are mounted on a horizontal shaft in a staggered fashion, with one hammer for each shock bar. As the shaft rotates slowly each of the hammers in turn tumbles, hitting its associated shock bar. A uniform rapping effect is thereby provided over all collecting plates in one row, which causes the collected dust to fall down in large agglomerates.

FLUE GAS DESULPHURISATION

Flue gas desulphurisation is achieved by employing a wet limestone-gypsum method. This process technology uses limestone powder as sorbent and at the end product gives gypsum. The process is composed of the following main parts:

- the flue gas desulphurisation system;
- the reagent storage and preparation system; and
- the gypsum dewatering and storage system

The flue gas enters the FGD Absorber spray tower from the bottom and flows upward. Inside of the FGD Absorber, the flue gas travels upward in counter current to a continuous spray of recycled slurry that cools down the flue gas and absorbs SO_2 and other acid gases such as HCl and HF. The flue gas exits the FGD Absorber through a mist eliminator section that removes entrained droplets of slurry. The sprayed slurry is collected at the bottom of the FGD Absorber and transferred to a tank where ambient air is injected to complete the chemical reactions. Fresh reagent is added to the tank where it reaches equilibrium with the bulk of the recycle slurry prior to being sprayed again in the FGD Absorber. The tank is equipped with agitators to keep the solid suspended.

LIMESTONE IS USED AS REAGENT IN THE PROCESS.

Limestone gravel is stored into two silos. Each silo is sized for a capacity of 314 m^3. Each silo is sized to provide 24 hours of limestone for the FGD running at 100% load with the performance coal. Two milling systems are provided to wet grind the limestone gravel to the required size. The prepared reagent slurry (suspension of powdered limestone in water) is stored in a tank and from this tank is fed to the FGD Absorber to replenish the reagent consumed in the absorption phase. Feeding rate is controlled based on a pH signal from the FGD Absorber. The raw limestone can be received from the existing Drax's limestone storage via dedicated conveyors or by truck. The conveyors nominal flow is 13 t/h with a maximum flow of 60 t/h.

GYPSUM DEWATERING AND STORAGE SYSTEM

The chemical reaction between SO_2 and limestone results in the formation of gypsum. A stream of the FGD Absorber slurry is bled from the system and sent to the Gypsum Dewatering and Storage System. The Gypsum Dewatering System is divided in to two stages as described below:

1. Hydrocyclones are used for the first stage of dewatering producing a stream of highly concentrated slurry rich in gypsum crystals; this stream is sent to the second stage where vacuum belt filters are used to remove the residual water and produce a dry cake of gypsum that can be then stored in a silo.

2. The silo is sized for a capacity of 2,660 m^3 to provide four days of storage for the FGD running at 100% load with the performance coal. From the silo the produced gypsum can be reclaimed and sent to either Drax's existing gypsum storage by conveyor or loaded onto trucks.

SELECTIVE CATALYTIC REDUCTION (SCR)

The NOx emissions are controlled by the low NOx firing system and the Selective Catalytic Reduction System (SCR), using anhydrous ammonia. The purpose of the SCR is to reduce the NOx in the flue gas by mixing vapour ammonia with flue gas at the boiler outlet. The SCR System is composed of three layers of catalyst and a catalyst chamber. Anhydrous ammonia is unloaded from a tanker truck to the two anhydrous ammonia storage tanks located in the ammonia storage area. Ammonia from the storage tanks is sent by forwarding pumps to the ammonia vaporisers, with excess ammonia recirculated back to the storage tank.

The SCR system is started up and shutdown in a sequence integrated with the operation of the steam generating unit. When the proper thermal operating environment is achieved, vaporised anhydrous ammonia is supplied to the ammonia injection grid located upstream of the reactor. The ammonia flow control unit consisting of dilution blowers, electric heaters, static mixer and ammonia flow control valve regulates the flow of anhydrous ammonia to the system.

4.0 BASELINE AND BACKGROUND DATA

Background data has been collected over a number of years at various locations (7 locations in total) within the Aire Valley to monitor the impact on local air quality from the operations of the three large power stations in the region. Data from these monitoring sites are provided below in Table 5.1

Table 5.1 Background data collected from the Aire Valley monitoring network (2007-2013).

Monitoring Station	2007-2013 average (ug/m^3)		
	NO_x	NO_2	SO_2
Hemmingbrough Landing Lane	19.0	16.9	3.86
Carr Lane	n/a	n/a	4.43
Downes Ground Farm	22.4	16.2	4.09
West Bank	22.4	16.4	4.59
Smeathall's Farm	28.8	20.4	4.83
Park Farm	n/a	n/a	15.6
Average	23.2	17.5	6.23

These data can be compared with the relevant Air Quality Standards in the table below. Table 5.2 Baseline Pollution Data used in the Assessment of Impacts at Sensitive Human Receptors.

Pollutant	Annual mean AQS (µg/m3)	Baseline concentration (µg/m3)	Source
NO_x	30 (ecology)	23.2	Aire Valley monitoring 2007 – 2013 (see table 5.1)
NO_2	40 (human)	17.5	
SO_2	n/a	6.2	
$PM_{2.5}$	20 (human)	10.8	Department for Environment Food and Rural Affairs (DEFRA) background concentration maps 2011.[1]
PM_{10}	40 (human)	17.9	
CO	10,000 (human)	115	Department for Environment Food and Rural Affairs (DEFRA) background concentration maps 2001 with 2014 factor applied.[2]
HCl	n/a	0.267	UKEAP: Acid Gas and Aerosol[3]

[1] Department for Environment Food and Rural Affairs (DEFRA) 2011 Based Background Maps for NO_x, NO_2, PM_{10} and $PM_{2.5}$, http://laqm.defra.gov.uk/maps/maps2011.html (Accessed September 2014)

[2] Part IV of the Environment Act 1995, Environment (Northern Ireland) Order 2002 Part III, Local Air Quality Management – Technical guidance LAQM.TG09, February 2009

[3] Department for Environment Food and Rural Affairs (DEFRA) Interactive Monitoring Networks Map, http://uk-air.defra.gov.uk/interactive-map (Accessed June 2014)

Pollutant	Annual mean AQS (µg/m3)	Baseline concentration (µg/m3)	Source
NH3	180 (human) 1 (ecology)	2.18	National Ammonia Monitoring Network (NAMN)4
HF	n/a	2.46	EPAQS[5]
As	0.003 (human -EPAQS) 0.006 (human - EU)	0.000637	UK Rural Heavy Metals Monitoring Network[6]
Total Cr	5 (human)	0.000749	
Cr(VI)	0.0002	0.000150 (Note 1)	
Cu	10 (human)	0.00300	
Cd	0.005 (human)	0.000112	
Pb	0.25 (human)	0.00630	
Hg	0.25 (human)	0.000983	
Ni	0.02 (human)	0.000571	
Se	1 (human)	0.000597	
V	5 (human)	0.00105	
Zn	50 (human)	0.0135	
(1) The ratio of Cr(VI) as a proportion of total Cr is interpolated as no monitoring of Cr(VI) is undertaken directly. The ratio is variable, depending upon local emission sources and local conditions. There are a number of ratios available: EPAQS[(7)] present information suggesting that Cr(VI) may constitute between 3% and 33% of total airborne chromium. The US Department of Health[(8)], suggests that Cr(VI) may constitute between 10% and 20% of total airborne chromium; and the Environment Agency suggest 20%. On the basis of the available evidence, a pragmatic ratio that 20% of total Cr occurs as Cr(VI) has been used in the assessment to derive the likely background concentration of Cr(VI) from monitored total chromium.			

In order to ensure that the White Rose plant will operate utilising BAT, it is necessary to be aware of current and forthcoming legislation and the nature of the emissions limits which are likely to be enforced taking into account operation in both Air mode and Oxy mode. The various criteria against which assessments of emissions (Process contributions - PCs) and impact on the current ambient concentrations (Predicted Environmental Concentrations – PECs) are outlined in the following tables.

[4] Department for Environment Food and Rural Affairs (DEFRA) National Ammonia Monitoring Network (NAMN) http://uk-air.defra.gov.uk/data/non-auto-data?uka_id=UKA00296&view=data&network=namn&year=2012&pollutant=default#view http://uk-air.defra.gov.uk/interactive-map (Accessed June 2014)

[5] Expert Panel on Air Quality Standards, Guidelines for Halogens and Hydrogen Halides in Ambient Air for Protecting Human Health Against Acute Irritancy Effects

[6] Department for Environment Food and Rural Affairs (DEFRA) Rural Heavy Metals Network http://uk-air.defra.gov.uk/networks/network-info?view=rm

(7) Expert Panel on Air Quality Standards (2009) Metals and Metalloids
(8) U.S. Department Of Health And Human Services Public Health Service Agency For Toxic Substances And Disease Registry (2008) Draft Toxicological Profile For Chromium

5.0 METHODOLOGY

Tables 5.1 and 5.2 lists the basic emissions parameters from the main OPP stack in Air mode and Oxy mode which would constitute a new emission point. Generally speaking, regulatory regimes have focused on compliance with concentrations, however, with CCS plants and particularly oxyfuel fired technology, comparing concentrations is not an accurate method of assessing the impacts of different plants and technologies.

DISPERSION MODEL

The operational impacts from the combustion process were assessed using the ADMS (Atmospheric Dispersion Modelling System) version 5.0. ADMS is one of a 'new generation' of dispersion models which describe the atmospheric boundary layer properties. ADMS allows for the modelling of dispersion under convective meteorological conditions using a skewed Gaussian concentration distribution. It is able to simulate the effects of terrain and building downwash simultaneously. It can also calculate concentrations for direct comparison with air quality standards or guidelines. Previous discussion with the Environment Agency regarding methodology, input data and application of the model has been undertaken and generally it was agreed that the methodology employed is acceptable.

MODELLING APPROACH AND PLANT ASSUMPTIONS

It is assumed that the plant will be operating for 8,760 hours per annum. With regard to air-mode, however, this scenario is extremely unlikely as the plant is not expected to be operating in this mode for any significant length of time. This assessment presents a worst case approach for both the air-mode and oxy-mode operation.

With regard to the operation of the auxiliary boiler, a number of cases were provided by Alstom for consideration. It is understood that the ASU will require 3 days conditioning from a warm start up and that the auxiliary boiler will operate in parallel during those days. Based on this, it is assumed that the auxiliary boiler will operate typically for 72 hours per annum. The boiler has been modelled in combination with both air-mode and oxy-mode parameters, although the worst case scenario involves operation in air mode with the auxiliary boiler operating and these results have been presented

The emissions and stack parameters for oxy-mode are presented in Table 5.2. These have been used in the modelling assessment to estimate pollutant concentrations at sensitive human and ecological receptors in the vicinity of the Project while operating under normal conditions.

The emission conditions during operations in oxy-mode vary with the regeneration of the adsorber medium in the flue gas drier. Temperature, actual volume flow rate, NOx concentrations and mass emissions will change during the regeneration cycle. In order to take into consideration these changing parameters during the operation of the Project, a time varying emissions profile has been used in the model.

For those pollutants which have emission limit values specified in the IED, a comparison has been made to the emission concentrations for the plant during every hour while operating in oxy-mode for one complete 8 hour cycle. These pollutants include NOx, SO_2 and PM and are presented in Table 5.3 to Table 5.5.

Table 5.1. Parameters associated with emissions in Air-mode operation

Parameter	Unit	Data
Stack Height	m	120
Flue diameter	m	5.5
Flue Area	m	23.8
Volume Flow Rate	Am^3/s	419
Emission Temperature	Celsius	51.5
Oxygen (actual)	% vol	4.3
Moisture (Actual)	% vol	13.04
Sulphur dioxide (SO_2)	g/s	50.8
Oxides of nitrogen (NO_x)	g/s	45.8
Particulate matter (PM)	g/s	3.47
Carbon monoxide (CO)	g/s	83.6
Hydrogen chloride (HCl)	g/s	1.77
Hydrogen fluoride (HF)	g/s	0.11
Non-methane volatile organic compounds (NMVOC)	g/s	5
Arsenic (As)	g/s	0.016
Cadmium (Cd)	g/s	0.0001
Chromium (Cr)	g/s	0.007
Copper (Cu)	g/s	0.007
Lead (Pb)	g/s	1.01
Mercury (Hg)	g/s	0.0008
Nickel (Ni)	g/s	0.02
Selenium (Se)	g/s	0.181
Vanadium (V)	g/s	0.012
Zinc (Zn)	g/s	0.013
Ammonia (NH_3)	g/s	0.233

Table 5.2. Parameters associated with emissions in Oxy-mode operation

Parameter	Units	Data	Comments
Stack height	m	120	
Stack diameter	m	1.1	
Flue Area	m^2	0.95	
Volume Flow Rate	Am^3/s	15.8	
Particulate Matter (PM)	g/s	0.25	
Sulphur Dioxide (SO_2)	g/s	0.6	Eventually slight peak but this should be negligible. Covered by the figure given.

Carbon monoxide (CO)	g/s	15	Consistent since not absorbed in drier bed
Hydrogen chloride (HCl)	g/s	1.00×10^{-3}	Consistent
Hydrogen fluoride (HF)	g/s	1.00×10^{-3}	Consistent
Non-methane VOC (NMVOC)	g/s	1.5	Eventually slight peak but this should be negligible. Covered by the figure given.
Arsenic (As)	g/s	0.008	Constant since solid deposits are most likely to be blown out at the beginning of the regeneration back to the SCR
Cadmium (Cd)	g/s	0.0004	As noted above
Chromium (Cr)	g/s	0.0025	As noted above
Copper (Cu)	g/s	0.0036	As noted above
Lead (Pb)	g/s	0.0045	As noted above
Mercury (Hg)	g/s	0.00015	As noted above
Nickel (Ni)	g/s	0.0088	As noted above
Selenium (Se)	g/s	0.082	As noted above
Vanadium (V)	g/s	0.006	As noted above
Zinc (Zn)	g/s	0.0065	As noted above
Ammonia (NH_3)	g/s	0.139	Optional SCR with NH_3 addition would be downstream GPU in the vent gas line.

It is important to note the significant difference in the emissions rate and associated data when comparing the plant operating in air mode and the plant operating in oxy mode. It is evident that the plant operating in oxy mode has significantly lower mass emissions when compared with the plant operating in oxy mode. The basis for the reduced mass of pollutants in the flue gas during oxy mode operation is due to a number of factors:

- Reduced volumetric flow rate due to re-circulation of flue gas
- removal of nitrogen from the influent combustion air (1ry, 2ndry and 3ry air) significantly reducing NOx production through the combustion process
- re-circulation of the flue gas back through the flue gas abatement systems resulting in an iterative increase in removal
- use of flue gas condenser to remove moisture from the CO_2 gas stream resulting in a reduction in the acid gases present in the flue gas

This reduction in the pollutants whilst operating in Oxy mode contributes to meeting the required CO_2 specification required by National Grid Carbon limited prior to compression of the CO_2 and onward transport via the pipeline to the storage site.

COMPARISON OF OPERATION AND EMISSIONS WITH IED (OXY MODE)

Table 6.3 shows the comparison of SO_2 emissions during oxy mode operation with the relevant species within the Industrial Emissions Directive limits (IED).

Parameter	**Units**	**Minimum**	**Maximum**	**Average**
Sulphur Dioxide (SO_2)	g/s	0.6	0.6	0.6

Normalised volume flow rate on wet base	Nm^3/h	56440	60822	56994
Emission concentration	mg/Nm^3	35.5	38.3	37.9
IED emission limit	mg/Nm^3	150	150	150
Emission concentration as percentage of IED emission limit	%	24	26	25.6

Table 5.4 shows the comparison of NOx emissions during oxy mode operation with the relevant species within the Industrial Emissions Directive limits (IED).

Parameter	Units	Minimum	Maximum	Average
Oxides of Nitrogen (NO_x)	**g/s**	0.92	3.72	1.28125
Normalised volume flow rate on wet base	**Nm3/h**	56440	60822	56994
Emission concentration	**mg/Nm^3**	58.7	220.2	79.6
IED emission limit	**mg/Nm^3**	150	150	150
Emission concentration as percentage of IED emission limit	**%**	39	147	53.0

Table 5.5 shows the comparison of particulate matter emissions during oxy mode operation with the relevant species within the Industrial Emissions Directive limits (IED).

Parameter	Units	Minimum	Maximum	Average
Particulate Matter (PM)	**g/s**	0.25	0.25	0.25
Normalised volume flow rate on wet base	**Nm^3/h**	56440	60822	56994
Emission concentration	**mg/Nm^3**	14.8	15.9	15.8
IED emission limit	**mg/Nm^3**	10	10	10
Emission concentration as percentage of IED emission limit	**%**	148	159	157.6

In Oxy mode, the emissions generated by the plant comply with IED limits for SO2 throughout the operational cycle, however, during the regeneration cycle of the drying beds which the power plant must employ to maintain

CO2 quality specifications, there are peaks in NOx emissions. For NOx emissions, there is an increased emission over a short period of time (less than an hour), with an average NOx emission across the operational cycle of 79.6mg/Nm3. Particulates exceed the IED limit by approximately 150% throughout the operational cycle of the power station in Oxy mode. However, in terms of mass emissions, the mass load generated is approximately 14 times lower than in air mode.

Drying beds are employed to remove moisture from the flue gas prior to the processing of the Carbon Dioxide and subsequent compression via the Gas Processing Unit (GPU).

During the operational loading of the drier NO_x is co-adsorbed together with the moisture in the pores of the desiccant bed. When the drier bed temperature reaches around 60°C the volatility of the NOx is high enough that it is released from the bed resulting in short term peak in NOx emissions.

ASSESSMENT OF COMPLIANCE WITH AIR QUALITY STANDARDS IN OXY- MODE.

Table 5.6 provides an overview of the assessment of emissions from the Power Plant operating in Oxy-mode.

Pollutant	Averaging Period	AQS	Baseline	PC	PC/ AQS	PEC	PEC/ AQS	Significance Criteria	Significance Criteria
		(µg/m³)	(µg/m³)	(µg/m³)	(%)	(µg/m³)	(%)	(IAQM)	(EA H1)
SO_2	15 minute (99.90th percentile)	266	12.5	3.46	1.3	15.9	6	Negligible	Not Significant
SO_2	1 hour (99.73rd percentile)	350	12.5	2.44	<1	14.9	4.3	Negligible	Not Significant
SO_2	24 hour (99.18th percentile)	125	6.23	0.505	<1	6.73	5.4	Negligible	Not Significant
NO_2	1 hour (99.79th percentile)	200	35	2.21	1.1	37.2	19	Negligible	Not Significant
NO_2	Annual	40	17.5	0.0841	<1	17.6	44	Negligible	Not Significant
PM_{10}	24 hour (90.41st percentile)	50	35.7	0.0808	<1	35.8	72	Negligible	Not Significant
PM_{10}	Annual	40	17.9	0.0227	<1	17.9	45	Negligible	Not Significant
$PM_{2.5}$	Annual	20	10.8	0.0227	<1	10.8	54	Negligible	Not Significant
CO	8 hour (maximum daily running)	10000	230	83.9	<1	314	3.1	Negligible	Not Significant
HCl	1 hour	750	0.267	8.43×10^{-3}	<1	0.275	<1	Negligible	Not Significant
HF	1 hour	160	2.46	8.43×10^{-3}	<1	2.47	1.5	Negligible	Not Significant
HF	Annual	16	2.46	6.56×10^{-4}	<1	2.46	15	Negligible	Not Significant
As (EPAQS guideline)	Annual	0.003	0.0006	7.27×10^{-4}	24	1.36×10^{-3}	46	Minor Adverse	Acceptable
Cd	Annual	0.01	0.00011	3.64×10^{-5}	<1	1.48×10^{-4}	3	Negligible	Not Significant
Cr (total)	1 hour max.	150.00	0.0015	0.0211	<1	0.0226	<1	Negligible	Not Significant
Cr (total)	Annual	5.00	0.00	2.27×10^{-4}	<1	9.76×10^{-4}	<1	Negligible	Not Significant

Pollutant	Averaging Period	AQS	Baseline	PC	PC/ AQS	PEC	PEC/ AQS	Significance Criteria	Significance Criteria
Cr (VI)[Note 1]	Annual	0.00	0.00	1.23 x 10^{-5}	6.1	1.62 x 10^{-4}	81	Minor Adverse	Unacceptable
Cu	1 hour max.	200.00	0.01	0.0304	<1	0.0364	<1	Negligible	Not Significant
Cu	Annual	10.00	0.00	3.27 x 10^{-4}	<1	3.33 x 10^{-3}	<1	Negligible	Not Significant
Pb	Annual	0.25	0.01	4.09 x 10^{-4}	<1	6.71 x 10^{-3}	2.7	Negligible	Not Significant
Hg	1 hour max.	7.50	0.00	1.26 x 10^{-3}	<1	3.23 x 10^{-3}	<1	Negligible	Not Significant
Hg	Annual	0.25	0.00	1.36 x 10^{-5}	<1	1.00 x 10^{-3}	<1	Negligible	Not Significant
Ni	Annual	0.02	0.00	8.00 x 10^{-4}	4	1.37 x 10^{-3}	6.9	Negligible	Not Significant
Se	1 hour max.	30.00	0.00	0.691	2.3	0.693	2.3	Negligible	Not Significant
Se	Annual	1.00	0.00	7.45 x 10^{-3}	<1	8.05 x 10^{-3}	<1	Negligible	Not Significant
V	24hr max.	1.00	0.00	8.03 x 10^{-3}	<1	0.101	1	Negligible	Not Significant
V	Annual	5.00	0.00	5.45 x 10^{-4}	<1	1.59 x 10^{-3}	<1	Negligible	Not Significant
Zn	1 hour max.	1000	0.027	0.0548	<1	0.819	<1	Negligible	Not Significant
Zn	Annual	50	0.0135	5.91 X 10^{-4}	<1	0.0141	<1	Negligible	Not Significant
NH_3	1 hour max.	2500	4.35	1.17	<1	5.52	<1	Negligible	Not Significant
NH_3	Annual	180	2.18	0.0126	<1	2.19	1.2	Negligible	Not Significant

When reviewing Table 5.6 only one species appears to generate an unacceptable result applying the Agency's H1 screening criteria. Chromium VI (Cr (VI) has been calculated assuming that of the total mass of chromium generated, 20% of this mass is as chromium VI. This estimate is based on guidance from EPAQS although actual data regarding chromium speciation suggests that 20% represents a significantly conservative estimate and hence a worst case scenario. When reviewing the data, the PC represents 6.1% of the relevant air quality standard whereas the baseline already exceeds the 70 % threshold for the PEC at 75% of the AQS hence resulting in an unacceptable result. For this reason the analysis of chromium VI needs to be placed carefully in context of both the research data regarding speciation of chromium VI and also the likely ambient conditions which are an order of magnitude greater than the PC.

All other species analysed are either acceptable or not significant when applying the Environment Agency's H1 screening criteria for the PC or PEC when operating in air mode.

Table 5.7 provides an overview of the assessment of emissions from the Power Plant operating in Air mode.

Pollutant	Averaging Period	AQS	Baseline	PC	PC/ AQS (%)	PEC	PEC/ AQS (%)	Significance (IAQM)	Significance (EA H1)
		(µg/m³)	(µg/m³)	(µg/m³)		(µg/m³)			
SO2	**15 minute (99.90th percentile)**	266	12.5	55	21	67.5	25	Minor adverse	Unacceptable

Pollutant	Averaging Period	AQS	Baseline	PC	PC/ AQS (%)	PEC	PEC/ AQS (%)	Significance (IAQM)	Significance (EA H1)
		(µg/m^3)	(µg/m^3)	(µg/m^3)		(µg/m^3)			
SO_2	1 hour (99.73rd percentile)	350	12.5	48.5	14	61	17	Minor adverse	Acceptable
SO_2	24 hour (99.18th percentile)	125	6.23	19.5	16	25.8	21	Minor adverse	Acceptable
NO_2	1 hour (99.79th percentile)	200	35	15.4	8	50.4	25	Negligible	Acceptable
NO_2	Annual	40	17.5	1.44	4	18.9	47	Negligible	Acceptable
PM_{10}	24 hour (90.41st percentile)	50	35.7	0.567	1	36.3	73	Negligible	Acceptable
PM_{10}	Annual	40	17.9	0.156	<1	18	45	Negligible	Not Significant
$PM_{2.5}$	Annual	20	10.8	0.156	<1	11	55	Negligible	Not Significant
CO	8 hour (maximum daily running)	10000	230	81.3	<1	311	3.1	Negligible	Not Significant
HCl	1 hour	750	0.267	2.43	<1	2.7	<1	Negligible	Not Significant
HF	1 hour	160	2.46	0.151	<1	2.61	1	Negligible	Not Significant
HF	Annual	16	2.46	0.0265	<1	2.49	16	Negligible	Not Significant
As (EPAQS guideline)	Annual	0.003	6.37×10^{-4}	7.20×10^{-4}	24	1.36×10^{-3}	45	Minor Adverse	Acceptable
Cd	Annual	0.005	1.12×10^{-4}	4.50×10^{-5}	<1	1.57×10^{-4}	3	Negligible	Not Significant
Cr (total)	1 hour max.	150	1.50×10^{-3}	9.62×10^{-3}	<1	0.0111	<1	Negligible	Not Significant
Cr (total)	Annual	5	7.49×10^{-4}	3.15×10^{-4}	<1	1.06×10^{-3}	<1	Negligible	Not Significant
Cr (VI) Note 1	Annual	0.0002	1.50×10^{-4}	1.70×10^{-5}	8	1.67×10^{-4}	83	Slight Adverse	Not acceptable
Cu	1 hour max.	200	6.00×10^{-3}	9.62×10^{-3}	<1	0.0156	<1	Negligible	Not Significant

Pollutant	Averaging Period	AQS	Baseline	PC	PC/ AQS (%)	PEC	PEC/ AQS (%)	Significance (IAQM)	Significance (EA H1)
		(µg/m³)	(µg/m³)	(µg/m³)		(µg/m³)			
Cu	Annual	10	3.00×10^{-3}	3.15×10^{-4}	<1	3.31×10^{-3}	<1	Negligible	Not Significant
Pb	Annual	0.25	6.30×10^{-3}	4.50×10^{-4}	<1	6.75×10^{-3}	2.7	Negligible	Not Significant
Hg	1 hour max.	7.5	1.97×10^{-3}	0.011	<1	0.013	<1	Negligible	Not Significant
Hg	Annual	0.25	9.83×10^{-4}	3.60×10^{-4}	<1	1.34×10^{-3}	<1	Negligible	Not Significant
Ni	Annual	0.02	5.71×10^{-4}	8.99×10^{-4}	4	1.47×10^{-3}	7	Negligible	Acceptable
Se	1 hour max.	30	1.19×10^{-3}	0.249	<1	0.25	<1	Negligible	Not Significant
Se	Annual	1	5.97×10^{-4}	8.14×10^{-3}	<1	8.74×10^{-3}	<1	Negligible	Not Significant
V	24hr max.	1	2.10×10^{-3}	5.99×10^{-3}	<1	8.09×10^{-3}	<1	Negligible	Not Significant
V	Annual	5	1.05×10^{-3}	5.40×10^{-4}	<1	1.59×10^{-3}	<1	Negligible	Not Significant
Zn	1 hour max.	1000	0.027	0.0179	<1	0.045	<1	Negligible	Not Significant
Zn	Annual	50	0.0135	5.85×10^{-4}	<1	0.0141	<1	Negligible	Not Significant
NH_3	1 hour max.	2500	4.35	0.32	<1	4.67	<1	Negligible	Not Significant
NH_3	Annual	180	2.18	0.0105	<1	2.19	1.2	Negligible	Not Significant

When reviewing the data associated with the operation of the plant in Air mode it is evident that for all species when considering the PEC, none of the air quality standards are breached. Assessment against the Environment Agency's H1 criteria identified that for SO_2 emissions, specifically with regard to the 15 minute mean, the PC represents 21% of the relevant AQS and the PEC represents 25% of the relevant AQS.

The modelling undertaken has assumed operation in Air mode for 100% of the year, however, in practice this would not occur. Assessment of arsenic shows a minor adverse effect when using the IAQM assessment criteria and an acceptable impact when applying the Agency's own assessment criteria.

The PEC associated with chromium (VI) is defined by H1 as not acceptable, however, the PEC is dominated by the background concentration in this instance with the PC for chromium (VI) representing 8% of the relevant AQS and the background concentration representing 75% of the AQS. As defined previously, chromium (VI) has been modelled assuming that it represents 20% of the total chromium load which based on data appears to be a significantly conservative estimate.

Table 5.8 Identifies any species where analysis of modelled impacts on air quality or habitats shows a potential for significant impact (deposition >1% of the critical load).

Operating Scenario	Summary data	Acid deposition	Nutrient-N deposition	NOx (weekly mean)	NOx 24 hr mean	SO_2 (Annual mean)	Ammonia (NH_3)	HF (weekly mean)	HF (24hr Mean)
Oxy mode	Cr (VI)	None	None	None	None	None	None	None	None
Air mode	SO_2, Cr (VI)	Humber, Skipwith Common, Thorne Moor	None	None	None	R. Derwent,Skipwith Common	None	None	None
Air mode plus Auxiliary Boiler	SO_2, Cr (VI)	Humber, Skipwith Common, Thorne Moor	None	None	None	R. Derwent,Skipwith Common	N/A	N/A	N/A

The table shows that for the following data sets generated from the modelled emissions from the plant operating in the 3 modes identified, potential significant impacts have been identified in the tables containing summary emissions data, acid deposition and SO_2 emissions. All other data sets do not show any significant impacts on the relevant air quality parameter (human health or ecology) or habitats and specific features associated with those habitats.

Assessment of Ecological impacts when operating in Oxy mode

A number of assessments have been undertaken which involve the assessment of emissions to atmosphere from the power plant operating in Oxy mode 100% of the year. Using the modelling data generated by the ADMS software, assessments for the following impacts and species have been undertaken for relevant habitats and associated features.

- Acid deposition
- Nutrient nitrogen deposition
- Oxides of nitrogen (NOx) concentrations
- Sulphur dioxide (SO_2) concentrations
- Ammonia concentrations
- Hydrogen fluoride concentrations

Table 5.9 Predicted Acid Deposition at Ecological Receptors (Annual Mean) in Oxy-mode

Site	APIS Habitat – main feature	APIS Habitat – broad habitat	Critical Load for Acid Deposition (keq ha^{-1} yr^{-1})	Background Acid Deposition (keq ha^{-1} yr^{-1})	PC (keq ha^{-1} yr^{-1})	PC/CL (%)	PEC (keq ha^{-1} yr^{-1})	PEC/CL (%)	Significance (EA H1)
Humber Estuary	Fixed dunes with herbaceous vegetation	Supralittoral sediment (acidic type)	0.643	2.48	1.06×10^{-3}	<1	2.48	386	Not Significant
		Supralittoral sediment (calcareous type)	4.856	2.48	1.06×10^{-3}	<1	2.48	51	Not Significant
	Dunes with *Hippophae rhamnoides*	n/a	0.643	2.48	1.06×10^{-3}	<1	2.48	386	Not Significant
Lower Derwent Valley	Neutral Grassland (calcareous type)	n/a	4.856	2.77	1.40×10^{-3}	<1	2.77	57	Not Significant
River Derwent	No habitat sensitive to acidification.	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Skipwith Common	European dry heaths	n/a	0.802	1.67	1.12×10^{-3}	<1	1.67	208	Not Significant
	Northern Atlantic wet heaths with *Erica tetralix*	n/a	0.802	1.67	1.12×10^{-3}	<1	1.67	208	Not Significant

Site	APIS Habitat – main feature	APIS Habitat – broad habitat	Critical Load for Acid Deposition (keq ha^{-1} yr^{-1})	Background Acid Deposition (keq ha^{-1} yr^{-1})	PC (keq ha^{-1} yr^{-1})	PC/CL (%)	PEC (keq ha^{-1} yr^{-1})	PEC/CL (%)	Significance (EA H1)
Thorne Moor	Degraded raised bogs still capable of natural regeneration	n/a	0.462	1.71	9.35×10^{-4}	<1	1.71	370	Not Significant
Meadow East of Orchard Farm	Neutral grassland (Mountain Hay Meadows)	n/a	4.7	1.61	1.91×10^{-3}	<1	1.61	34	Not Significant

When considering acid deposition (Annual Mean) in Oxy mode and its impact on the relevant habitats and features, all PCs are less than 1% of the AQS although the PECs are exceeded at a number of sites identified with features sensitive to acid deposition.

Table 5.10 shows the Predicted Nutrient Nitrogen Deposition at Ecological Receptors (Annual Mean) in Oxy-mode

Sites	APIS Habitat feature	Sub feature	Critical Load for Nutrient Nitrogen Deposition (kgN ha^{-1} yr^{-1})	Background Nutrient Nitrogen Deposition (kgN ha^{-1} yr^{-1})	PC (kgN ha^{-1} yr^{-1})	PC/CL (%)	PEC (kgN ha^{-1} yr^{-1})	PEC/CL (%)	Significance (EA H1)
Humber Estuary	Fixed dunes with herbaceous vegetation (grey dunes) (H2130)	Supralittoral sediment (acidic type)	8	31.1	7.09 x 10^{-3}	<0.1	31.1	389	Not Significant
		Supralittoral sediment (calcareous type)	10	31.1	7.09 x 10^{-3}	<0.1	31.1	311	Not Significant
	Embryonic shifting dunes	n/a	10	31.1	7.09 x 10^{-3}	<0.1	31.1	311	Not Significant
	shifting dunes along the shoreline with *Ammophila arenaria* (white dunes)	n/a	10	31.1	7.09 x 10^{-3}	<0.1	31.1	311	Not Significant
	Coastal Lagoons	n/a	20	57.7	7.09 x 10^{-3}	<0.1	57.7	288	Not Significant
	Estuaries	n/a	20	31.1	7.09 x 10^{-3}	<0.1	31.1	155	Not Significant
	Salicornia and other annuals colonising mud and sand	n/a	20	31.1	7.09 x 10^{-3}	<0.1	31.1	155	Not Significant

Sites	APIS Habitat feature	Sub feature	Critical Load for Nutrient Nitrogen Deposition (kgN ha^{-1} yr^{-1})	Background Nutrient Nitrogen Deposition (kgN ha^{-1} yr^{-1})	PC (kgN ha^{-1} yr^{-1})	PC/CL (%)	PEC (kgN ha^{-1} yr^{-1})	PEC/CL (%)	Significance (EA H1)
	Pioneer, low-mid, mid-upper saltmarshes	n/a	20	31.1	7.09×10^{-3}	<0.1	31.1	155	Not Significant
	Dunes with *Hippophae rhamnoides*	n/a	No comparable habitat with established critical load estimate available	31.1	7.09×10^{-3}	n/a	31.1	n/a	n/a
	Mudflats and sandflats not covered by seawater at low tide	n/a	No comparable habitat with established critical load estimate available	31.1	7.09×10^{-3}	n/a	31.1	n/a	n/a
Lower Derwent Valley	Lowland Hay meadows	Neutral Grassland (acid type)	20	35.4	9.35×10^{-3}	<1	35.4	177	Not Significant
		Neutral grassland (calcareous type)	20	35.4	9.35×10^{-3}	<1	35.4	177	Not Significant
River Derwent	No sensitive ecological habitat present	n/a	No comparable habitat with established critical load estimate available	n/a	n/a	n/a	n/a	n/a	n/a
Skipwith Common	European dry heaths	n/a	10	20.2	7.54×10^{-3}	<1	20.2	202	Not Significant

Sites	APIS Habitat feature	Sub feature	Critical Load for Nutrient Nitrogen Deposition (kgN ha^{-1} yr^{-1})	Background Nutrient Nitrogen Deposition (kgN ha^{-1} yr^{-1})	PC (kgN ha^{-1} yr^{-1})	PC/CL (%)	PEC (kgN ha^{-1} yr^{-1})	PEC/CL (%)	Significance (EA H1)
	Northern Atlantic wet heaths with *Erica tetralix*	n/a	10	20.2	7.54×10^{-3}	<1	20.2	202	Not Significant
Thorne Moor	Degraded raised bogs still capable of natural regeneration	n/a	5	20.7	6.24×10^{-3}	<1	20.7	415	Not Significant
Meadow East of Orchard Farm	Neutral grassland (Mountain Hay Meadows)	n/a	10	19.8	0.0127	<1	19.8	198	Not Significant

When considering nutrient nitrogen deposition in Oxy mode and its impact on the relevant habitats and features, all PCs are less than 1% of the AQS although the PECs are exceeded at all sites identified with features sensitive to nutrient nitrogen deposition.

Table 5.11 Predicted NO_X at Ecological Receptors (Annual Mean) in Oxy-mode

Sites	Critical Level	Background Conditions	PC (µg m^{-3})	PC/ AQS (%)	PEC (µg m^{-3})	PEC/AQS (%)	Significance (EA H1)
	(µg m^{-3})	(µg m^{-3})					
Humber Estuary	30	18	0.0101	<1	18	60	Not Significant
Lower Derwent Valley	30	12.8	0.0138	<1	12.8	43	Not Significant
River Derwent	30	13.8	0.0731	<1	13.8	46	Not Significant
Skipwith Common	30	12.9	0.0103	<1	12.9	43	Not Significant
Thorne Moor	30	15.7	8.84×10^{-3}	<1	15.7	53	Not Significant
Meadow East of Orchard Farm	30	14.8	0.0186	<1	14.8	49	Not Significant

When considering NOx emissions (Annual Mean) in Oxy mode and its impact on ecological receptors, all PCs are less than 1% of the AQS and the PEC does not exceed the AQS at any of the sites identified.

Table 5.12 Predicted NOX at Ecological Receptors (24 hour Mean) in Oxy-mode

Sites	Critical Level (µg m^{-3})	Background Conditions (µg m^{-3})	PC (µg m^{-3})	PC/AQS (%)	PEC (µg m^{-3})	PEC/AQS (%)	Significance (EA H1)
Humber Estuary	75	36	0.103	<1	36.1	48	Not Significant
Lower Derwent Valley	75	25.6	0.173	<1	25.7	34	Not Significant
River Derwent	75	27.6	0.728	<1	28.3	38	Not Significant
Skipwith Common	75	25.9	0.113	<1	26	35	Not Significant

Sites	Critical Level (µg m^{-3})	Background Conditions (µg m^{-3})	PC (µg m^{-3})	PC/AQS (%)	PEC (µg m^{-3})	PEC/AQS (%)	Significance (EA H1)
Thorne Moor	75	31.5	0.101	<1	31.6	42	Not Significant
Meadow East of Orchard Farm	75	29.5	0.489	<1	30	40	Not Significant

When considering NOx emissions (24hr Mean) in Oxy mode and its impact on ecological receptors, all PCs are less than 1% of the AQS and the PEC does not exceed the AQS at any of the sites identified.

Table 5.13 Predicted SO_2 at Ecological Receptors (Annual Mean) in Oxy-mode

Sites	Critical Level (µg m^{-3})	Background Conditions (µg m^{-3})	PC (µg m^{-3})	PC/ AQS (%)	PEC (µg m^{-3})	PEC/AQS (%)	Significance (EA H1)
Humber Estuary	10	5.39	4.68×10^{-3}	<1	5.39	54	Not Significant
Lower Derwent Valley	10	5.99	6.12×10^{-3}	<1	6	60	Not Significant
River Derwent	10	5.76	0.0332	<1	5.79	58	Not Significant
Skipwith Common	10	6.75	4.95×10^{-3}	<1	6.75	68	Not Significant
Thorne Moor	10	4.81	4.12×10^{-3}	<1	4.81	48	Not Significant
Meadow East of Orchard Farm	10	6.23	8.37×10^{-3}	<1	6.23	62	Not Significant

When considering SO_2 emissions in Oxy mode and its impact on ecological receptors, all PCs are less than 1% of the AQS and the PEC does not exceed the AQS at any of the sites identified.

Table 5.14 Predicted Ammonia Concentrations at Ecological Receptors (Annual Mean) in Oxy-mode

Sites	Critical Level (µg m^{-3})	Background Conditions (µg m^{-3})	PC (µg m^{-3})	PC/ AQS (%)	PEC (µg m^{-3})	PEC/AQS (%)	Significance (EA H1)
Humber Estuary	1	2.18	1.08×10^{-3}	<1	2.18	218	Not Significant
Lower Derwent Valley	1	2.18	1.42×10^{-3}	<1	2.18	218	Not Significant
River Derwent	1	2.18	7.70×10^{-3}	<1	2.18	218	Not Significant
Skipwith Common	1	2.18	1.15×10^{-3}	<1	2.18	218	Not Significant
Thorne Moor	1	2.18	9.55×10^{-4}	<1	2.18	218	Not Significant
Meadow East of Orchard Farm	1	2.18	1.94×10^{-3}	<1	2.18	218	Not Significant

When considering ammonia emissions in Oxy mode and its impact on ecological receptors, all PCs are less than 1% of the AQS, however, the PECs exceed the AQS at all the sites identified as being sensitive to ammonia emissions.

Table 5.15 Predicted Hydrogen Fluoride at Ecological Receptors (Weekly Mean) in Oxy-mode

Sites	Critical Level (µg m^{-3})	Background Conditions (µg m^{-3})	PC (µg m^{-3})	PC/ AQS (%)	PEC (µg m^{-3})	PEC/AQS (%)	Significance (EA H1)
Humber Estuary	0.5	1.23	3.29×10^{-5}	<1	1.23	246	Not Significant
Lower Derwent Valley	0.5	1.23	5.15×10^{-5}	<1	1.23	246	Not Significant
River Derwent	0.5	1.23	2.429×10^{-4}	<1	1.23	246	Not Significant
Skipwith Common	0.5	1.23	3.60×10^{-5}	<1	1.23	246	Not Significant

Sites	Critical Level ($\mu g\ m^{-3}$)	Background Conditions ($\mu g\ m^{-3}$)	PC ($\mu g\ m^{-3}$)	PC/ AQS (%)	PEC ($\mu g\ m^{-3}$)	PEC/AQS (%)	Significance (EA H1)
Thorne Moor	0.5	1.23	2.55×10^{-5}	<1	1.23	246	Not Significant
Meadow East of Orchard Farm	0.5	1.23	1.15×10^{-4}	<1	1.23	246	Not Significant

When considering Hydrogen Fluoride (Weekly Mean) emissions in Oxy mode and its impact on ecological receptors, all PCs are less than 1% of the AQS, however, the PECs all exceed the relevant AQS at all the sites identified as being sensitive to Hydrogen Fluoride emissions.

Table 5.16 Predicted Hydrogen Fluoride at Ecological Receptors (24 hour Mean) in Oxy-mode

Sites	Critical Level ($\mu g\ m^{-3}$)	Background Conditions ($\mu g\ m^{-3}$)	PC ($\mu g\ m^{-3}$)	PC/ AQS (%)	PEC ($\mu g\ m^{-3}$)	PEC/AQS (%)	Significance (EA H1)
Humber Estuary	5	1.45	7.81×10^{-5}	<1	1.45	29	Not Significant
Lower Derwent Valley	5	1.45	1.14×10^{-4}	<1	1.45	29	Not Significant
River Derwent	5	1.45	4.97×10^{-4}	<1	1.45	29	Not Significant
Skipwith Common	5	1.45	1.01×10^{-4}	<1	1.45	29	Not Significant
Thorne Moor	5	1.45	1.02×10^{-4}	<1	1.45	29	Not Significant
Meadow East of Orchard Farm	5	1.45	2.73 x 10-4	<1	1.45	29	Not Significant

When considering Hydrogen Fluoride (24 Hr Mean) emissions in Oxy mode and its impact on ecological receptors, all PCs are less than 1% of the AQS and the PECs do not exceed the AQS at any the sites identified as being sensitive to Hydrogen Fluoride emissions.

Air mode tables regarding ecological impacts.

Table 5.17 Predicted Acid Deposition at Ecological Receptors (Annual Mean) in Air mode

Site	APIS Habitat – main feature	APIS Habitat – broad habitat	Critical Load for Acid Deposition (keq ha^{-1} yr^{-1})	Background Acid Deposition (keq ha^{-1} yr^{-1})	PC (keq ha^{-1} yr^{-1})	PC/ CL (%)	PEC (keq ha^{-1} yr^{-1})	PEC/ CL	Significance
Humber Estuary	Fixed dunes with herbaceous vegetation	Supralittoral sediment (acidic type)	0.643	2.48	0.0368	6	2.52	391	Unacceptable
		Supralittoral sediment (calcareous type)	4.856	2.48	0.0368	<1	2.52	52	Not Significant
	Dunes with Hippophae rhamnoides	n/a	0.643	2.48	0.0368	6	2.52	391	Unacceptable
Lower Derwent Valley	Neutral Grassland (calcareous type)	n/a	4.856	2.77	0.047	<1	2.81	58	Not Significant
River Derwent	NO habitat sensitive to acidification.	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Skipwith Common	European dry heaths	n/a	0.802	1.67	0.0417	5	1.71	213	Unacceptable
	Northern Atlantic wet heaths with Erica tetralix	n/a	0.802	1.67	0.0417	5	1.71	213	Unacceptable
Thorne Moor	Degraded raised bogs still capable of natural regeneration	n/a	0.462	1.71	0.031	7	1.74	377	Unacceptable
Meadow East of Orchard Farm	Neutral grassland (Mountain Hay Meadows)	n/a	4.7	1.61	0.0461	<1	1.66	35	Not Significant

When considering Acid deposition (Annual Mean) emissions in Air mode and its impact on ecological receptors, a number of PCs exceed the 1% threshold of the relevant critical load for specific habitat features. However, when considering the PECs, the background deposition at each location is the dominant factor where PCs do exceed the 1% threshold with each site already exceeding the critical load by a significant margin with the modelled impact of the power plant resulting in a relatively minor increase in acid deposition. This can be demonstrated by considering the relevant habitats associated with the Humber Estuary where the background acid deposition represents 98.4% of the PEC with the PC representing just 1.6% of the PEC. A similar scenario occurs with both Skipwith Common and Thorne Moor where the background acid deposition represents 97.7% and 98.2% of the respective PECS. In addition it is noted that when interrogating the citations for the relevant habitats and features, air pollution does not appear to be identified as a significant contributing factor to the status of the habitat.

Table 5.18 Predicted Nutrient Nitrogen Deposition at Ecological Receptors (Annual Mean) in Air mode

Sites	APIS Habitat feature	Sub feature	Critical Load for Nutrient Nitrogen Deposition (kgN ha^{-1} yr^{-1})	Background Nutrient Nitrogen Deposition (kgN ha^{-1} yr^{-1})	PC (kgN ha^{-1} yr^{-1})	PC/CL (%)	PEC (kgN ha^{-1} yr^{-1})	PEC/CL (%)	Significance
Humber Estuary	Fixed dunes with herbaceous vegetation (grey dunes) (H2130)	Supralittoral sediment (acidic type)	8	31.08	0.0397	<1	31.1	389	Not Significant
		Supralittoral sediment (calcareous type)	10	31.08	0.0397	<1	31.1	311	Not Significant
	Embryonic shifting dunes	n/a	10	31.08	0.0397	<1	31.1	311	Not Significant
	shifting dunes along the shoreline with Ammophila arenaria (white dunes)	n/a	10	31.08	0.0397	<1	31.1	311	Not Significant
	Coastal Lagoons	n/a	20	57.68	0.0397	<1	57.7	289	Not Significant
	Estuaries	n/a	20	31.08	0.0397	<1	31.1	156	Not Significant
	Salicornia and other annuals colonising mud and sand	n/a	20	31.08	0.0397	<1	31.1	156	Not Significant
	Pioneer, low-mid, mid-upper saltmarshes	n/a	20	31.08	0.0397	<1	31.1	156	Not Significant

Sites	APIS Habitat feature	Sub feature	Critical Load for Nutrient Nitrogen Deposition (kgN ha^{-1} yr^{-1})	Background Nutrient Nitrogen Deposition (kgN ha^{-1} yr^{-1})	PC (kgN ha^{-1} yr^{-1})	PC/CL (%)	PEC (kgN ha^{-1} yr^{-1})	PEC/CL (%)	Significance
	Dunes with Hippophae rhamnoides	n/a	No comparable habitat with established critical load estimate available	31.08	0.0397	n/a	n/a	n/a	n/a
	Mudflats and sandflats not covered by seawater at low tide	n/a	No comparable habitat with established critical load estimate available	31.08	0.0397	n/a	n/a	n/a	n/a
Lower Derwent Valley	Lowland Hay meadows	Neutral Grassland (acid type)	20	35.4	0.0489	<1	35.5	177	Not Significant
		Neutral grassland (calcareous type)	20	35.4	0.0489	<1	35.5	177	Not Significant
River Derwent	No sensitive ecological habitat present	n/a	No comparable habitat with established critical load estimate available	n/a	n/a	n/a	n/a	n/a	n/a
Skipwith Common	European dry heaths	n/a	10	20.2	0.0442	<1	20.2	202	Not Significant

Sites	APIS Habitat feature	Sub feature	Critical Load for Nutrient Nitrogen Deposition (kgN ha^{-1} yr^{-1})	Background Nutrient Nitrogen Deposition (kgN ha^{-1} yr^{-1})	PC (kgN ha^{-1} yr^{-1})	PC/CL (%)	PEC (kgN ha^{-1} yr^{-1})	PEC/CL (%)	Significance
	Northern Atlantic wet heaths with Erica tetralix	n/a	10	20.2	0.0442	<1	20.2	202	Not Significant
Thorne Moor	Degraded raised bogs still capable of natural regeneration	n/a	5	20.7	0.0337	<1	20.8	415	Not Significant
Meadow East of Orchard Farm	Neutral grassland (Mountain Hay Meadows)	n/a	10	19.8	0.0443	<1	19.8	198	Not Significant

When considering the Nutrient nitrogen deposition associated with operating in Air mode, all PCs are less than the 1% screening threshold and hence the impact from the power station is deemed not significant at all sites and associated habitats listed.

Table 5.19 Predicted NOX at Ecological Receptors (Annual Mean) in Air mode

Sites	Critical Level	Background Conditions	PC (µg m^{-3})	PC/ AQS (%)	PEC (µg m^{-3})	PEC/AQS (%)	Significance
	(µg m^{-3})	(µg m^{-3})					
Humber Estuary	30	15	0.233	<1	15.3	51	Not Significant
Lower Derwent Valley	30	12.8	0.287	<1	13.1	44	Not Significant
River Derwent	30	13.8	1.46	5	15.3	51	Acceptable
Skipwith Common	30	12.9	0.26	<1	13.2	44	Not Significant
Thorne Moor	30	15.8	0.198	<1	16	53	Not Significant

Sites	Critical Level	Background Conditions	PC (µg m-3)	PC/ AQS (%)	PEC (µg m-3)	PEC/AQS (%)	Significance
	(µg m-3)	(µg m-3)					
Meadow East of Orchard Farm	30	14.8	0.26	<1	15	50	Not Significant

When considering the predicted NOx concentrations associated with operating in Air mode, all PCs are less than the 1% screening threshold, except for the River Derwent (PC = 5% of AQS), however, the PEC represents 51% of the AQS and hence the impact from the power station is deemed not significant at all sites and associated habitats listed.

Table 5.20 Predicted NO_X at Ecological Receptors (24hr Mean) in Air mode

Sites	Critical Level	Background Conditions	PC (µg m-3)	PC/AQS (%)	PEC (µg m-3)	PEC/AQS (%)	Significance
	(µg m-3)	(µg m-3)					
Humber Estuary	75	30	2.71	4	34.2	44	Not Significant
Lower Derwent Valley	75	25.6	3.15	4	28.1	38	Not Significant
River Derwent	75	27.6	14.2	19	41.1	56	Acceptable
Skipwith Common	75	25.9	2.83	4	28	38	Not Significant
Thorne Moor	75	31.6	1.97	3	34.8	45	Not Significant
Meadow East of Orchard Farm	75	29.5	8.41	11	37.9	51	Acceptable

When considering the predicted NOx concentrations (24hr mean) associated with operating in Air mode, all PCs are less than the 1% screening threshold, except for the River Derwent (PC = 5% of AQS), however, the PEC represents 51% of the AQS and hence the impact from the power station is deemed not significant at all sites and associated habitats listed.

Table 5.21 Predicted SO_2 at Ecological Receptors (Annual Mean) in Air mode

Sites	Critical Level (µg m^{-3})	Background Conditions (µg m^{-3})	PC (µg m^{-3})	PC/ AQS (%)	PEC (µg m^{-3})	PEC/AQS (%)	Significance
Humber Estuary	10	5.39	0.259	3	5.65	56	Acceptable
Lower Derwent Valley	10	5.99	0.318	3	6.31	63	Acceptable
River Derwent	10	5.76	1.62	16	7.38	74	Unacceptable
Skipwith Common	10	6.75	0.288	3	7.04	70	Unacceptable
Thorne Moor	10	4.53	0.219	2	4.75	47	Acceptable
Meadow East of Orchard Farm	10	6.23	0.288	3	6.52	65	Acceptable

When considering the predicted SO_2 concentrations (Annual mean) associated with operating in Air mode, all PCs exceed the 1% screening threshold. The PECs exceed the 70% screening threshold at the River Derwent and also at Skipwith Common. The PEC at the Skipwith Common fractionally exceeds the 70% threshold with the background concentration significantly dominating the PEC (95.9%). The River Derwent is significantly closer to the site resulting in a greater PC of 16% of the AQS. The PEC exceeds the 70% threshold by 4% with the background again dominating the PEC (78%). The modelling of emissions in air mode is based on the assumption that the plant will operate for 100% of the year, following the commissioning phase of the project, this would not occur and indeed operation in air mode would be restricted by the Emissions Performance Standard.

Table 5.22 Predicted Ammonia Concentrations at Ecological Receptors (Annual Mean) in Air mode

Sites	Critical Level (µg m^{-3})	Background Conditions (µg m^{-3})	PC (µg m^{-3})	PC/ AQS (%)	PEC (µg m^{-3})	PEC/AQS (%)	Significance
Humber Estuary	1	2.18	1.19×10^{-3}	<1	2.18	218	Not Significant
Lower Derwent Valley	1	2.18	1.46×10^{-3}	<1	2.18	218	Not Significant
River Derwent	1	2.18	7.42×10^{-3}	<1	2.18	218	Not Significant
Skipwith Common	1	2.18	1.32×10^{-3}	<1	2.18	218	Not Significant
Thorne Moor	1	2.18	1.00×10^{-3}	<1	2.18	218	Not Significant
Meadow East of	1	2.18	1.32×10^{-3}	<1	2.18	218	Not Significant

Orchard Farm								

When considering the ammonia emissions generated by the power plant operating in Air mode, the PCs at each of the sites is less than 1% of the relevant AQS and hence screens out as not significant.

Table 5.23 Predicted Hydrogen Fluoride at Ecological Receptors (Weekly Mean) in Air mode

Sites	Critical Level ($\mu g\ m^{-3}$)	Background Conditions ($\mu g\ m^{-3}$)	PC ($\mu g\ m^{-3}$)	PC/ AQS (%)	PEC ($\mu g\ m^{-3}$)	PEC/AQS (%)	Significance
Humber Estuary	0.5	1.23	2.23×10^{-3}	<1	1.23	246	Not Significant
Lower Derwent Valley	0.5	1.23	3.45×10^{-3}	<1	1.23	247	Not Significant
River Derwent	0.5	1.23	0.0132	3	1.24	249	Not Significant
Skipwith Common	0.5	1.23	2.69×10^{-3}	<1	1.23	247	Not Significant
Thorne Moor	0.5	1.23	1.78×10^{-3}	<1	1.23	246	Not Significant
Meadow East of Orchard Farm	0.5	1.23	7.26×10^{-3}	1	1.24	247	Not Significant

When considering the Hydrogen Fluoride emissions (Weekly Mean) and impact at various ecological receptors, all PCs are less than the 10% screening threshold and hence screen out as insignificant.

Table 5.24 Predicted Hydrogen Fluoride at Ecological Receptors (24hr Mean) in Air mode

Sites	Critical Level ($\mu g\ m^{-3}$)	Background Conditions ($\mu g\ m^{-3}$)	PC ($\mu g\ m^{-3}$)	PC/ AQS (%)	PEC ($\mu g\ m^{-3}$)	PEC/AQS (%)	Significance
Humber Estuary	5	1.45	6.51×10^{-3}	<1	1.46	29	Not Significant
Lower Derwent Valley	5	1.45	7.55×10^{-3}	<1	1.46	29	Not Significant
River Derwent	5	1.45	0.034	<1	1.49	30	Not Significant
Skipwith Common	5	1.45	6.79×10^{-3}	<1	1.46	29	Not Significant

Sites	Critical Level (µg m-3)	Background Conditions (µg m-3)	PC (µg m-3)	PC/ AQS (%)	PEC (µg m-3)	PEC/AQS (%)	Significance
Thorne Moor	5	1.45	4.72 x 10^{-3}	<1	1.46	29	Not Significant
Meadow East of Orchard Farm	5	1.45	0.0202	<1	1.47	29	Not Significant

When considering the Hydrogen Fluoride emissions (24Hr Mean) and impact at various ecological receptors, all PCs are less than the 10% screening threshold and hence screen out as insignificant.

Table 5.25 Summary of Maximum Predicted Impacts at Off-site Locations, for any Meteorological Year Operating in Air-Mode combined with Auxiliary Boiler during start-up in Air mode

Pollutant	Averaging Period	AQS	Baseline	PC	PC/ AQS (%)	PEC	PEC/ AQS (%)	Significance	Significance
		(µg/m3)	(µg/m3)	(µg/m3)		(µg/m3)		(IAQM)	(H1)
SO_2	15 minute (99.90th percentile)	266	12.5	73.1	27	85.6	32	Minor adverse	Acceptable
SO_2	1 hour (99.73rd percentile)	350	12.5	54.7	16	67.1	19	Minor adverse	Acceptable
SO_2	24 hour (99.18th percentile)	125	6.23	21.4	17	33.8	27	Minor adverse	Acceptable
NO_2	1 hour (99.79th percentile)	200	35	21.2	11	56.2	28	Minor adverse	Acceptable
NO_2	Annual	40	17.5	1.44	4	18.9	47	Negligible	Acceptable
PM_{10}	24 hour (90.41st percentile)	50	35.7	1.34	3	37	74	Negligible	Not Significant
PM_{10}	Annual	40	17.9	0.157	<1	17.9	45	Negligible	Not Significant
$PM_{2.5}$	Annual	20	10.8	0.157	<1	10.8	55	Negligible	Not Significant
CO	8 hour (maximum daily running)	10000	230	86.7	<1	317	3	Negligible	Not Significant

Table 5.26 Predicted Acid Deposition at Ecological Receptors (Annual Mean) in Air-Mode combined with Auxiliary Boiler during start-up in Air mode

Site	APIS Habitat – main feature	APIS Habitat – broad habitat	Critical Load for Acid Deposition (keq ha^{-1} yr^{-1})	Background Acid Deposition (keq ha^{-1} yr^{-1})	PC (keq ha^{-1} yr^{-1})	PC/CL (%)	PEC (keq ha^{-1} yr^{-1})	PEC/CL	Significance
Humber Estuary	Fixed dunes with herbaceous vegetation	Supralittoral sediment (acidic type)	0.643	2.48	0.0368	6	2.52	391	Unacceptable
		Supralittoral sediment (calcareous type)	4.856	2.48	0.0368	<1	2.52	52	Not Significant
	Dunes with Hippophae rhamnoides	n/a	0.643	2.48	0.0368	6	2.52	391	Unacceptable
Lower Derwent Valley	Neutral Grassland (calcareous type)	n/a	4.856	2.77	0.0471	<1	2.82	58	Not Significant
River Derwent	NO habitat sensitive to acidification.	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Skipwith Common	European dry heaths	n/a	0.802	1.67	0.0417	5	1.71	213	Unacceptable
	Northern Atlantic wet heaths with Erica tetralix	n/a	0.802	1.67	0.0417	5	1.71	213	Unacceptable
Thorne Moor	Degraded raised bogs still capable of natural regeneration	n/a	0.462	1.71	0.031	7	1.74	377	Unacceptable
Meadow East of Orchard Farm	Neutral grassland (Mountain Hay Meadows)	n/a	4.7	1.61	0.0426	<1	1.65	35	Not Significant

When considering Acid deposition (Annual Mean) emissions in Air mode with the auxiliary boiler operating and its impact on ecological receptors, a number of PCs exceed the 1% threshold of the relevant critical load for specific habitat features. However, when considering the PECs, the background deposition at each location is the dominant factor where the PCs do exceed the 1% threshold with each site already exceeding the critical load by a significant margin. The modelled impact of the power plant results in a relatively minor increase in acid deposition. This can be demonstrated by considering the relevant habitats associated with the Humber Estuary where the background acid deposition represents 98.4% of the PEC with the PC representing just

1.6% of the PEC. A similar scenario occurs with both Skipwith Common and Thorne Moor where the background acid deposition represents 97.7% and 98.2% of the respective PECS. In addition it is noted that when interrogating the citations for the relevant habitats and features, air pollution does not appear to be identified as a significant contributing factor to the status of the habitat.

Table 5.27 Predicted Nutrient Nitrogen Deposition at Ecological Receptors (Annual Mean) in Air-Mode combined with Auxiliary Boiler during start-up in Air mode

Sites	**APIS Habitat feature**	**Sub feature**	**Critical Load for Nutrient Nitrogen Deposition (kgN ha^{-1} yr^{-1})**	**Background Nutrient Nitrogen Deposition (kgN ha^{-1} yr^{-1})**	**PC (kgN ha^{-1} yr^{-1})**	**PC/CL (%)**	**PEC (kgN ha^{-1} yr^{-1})**	**PEC/CL (%)**	**Significance**
Humber Estuary	Fixed dunes with herbaceous vegetation (grey dunes) (H2130)	Supralittoral sediment (acidic type)	8	31.08	0.0398	<1	31.1	389	Not Significant
		Supralittoral sediment (calcareous type)	10	31.08	0.0398	<1	31.1	311	Not Significant
	Embryonic shifting dunes	n/a	10	31.08	0.0398	<1	31.1	311	Not Significant
	shifting dunes along the shoreline with Ammophila arenaria (white dunes)	n/a	10	31.08	0.0398	<1	31.1	311	Not Significant
	Coastal Lagoons	n/a	20	57.68	0.0398	<1	31.1	289	Not Significant
	Estuaries	n/a	20	31.08	0.0398	<1	31.1	156	Not Significant
	Salicornia and other annuals colonising mud and sand	n/a	20	31.08	0.0398	<1	31.1	156	Not Significant
	Pioneer, low-mid, mid-upper saltmarshes	n/a	20	31.08	0.0398	<1	31.1	156	Not Significant
	Dunes with Hippophae rhamnoides	n/a	No comparable habitat with established critical load estimate available	n/a	n/a	n/a	n/a	n/a	n/a

Sites	APIS Habitat feature	Sub feature	Critical Load for Nutrient Nitrogen Deposition (kgN ha^{-1} yr^{-1})	Background Nutrient Nitrogen Deposition (kgN ha^{-1} yr^{-1})	PC (kgN ha^{-1} yr^{-1})	PC/CL (%)	PEC (kgN ha^{-1} yr^{-1})	PEC/CL (%)	Significance
	Mudflats and sandflats not covered by seawater at low tide	n/a	No comparable habitat with established critical load estimate available	n/a	n/a	n/a	n/a	n/a	n/a
Lower Derwent Valley	Lowland Hay meadows	Neutral Grassland (acid type)	20	35.4	0.049	<1	35.4	177	Not Significant
		Neutral grassland (calcareous type)	20	35.4	0.049	<1	35.4	177	Not Significant
River Derwent	No sensitive ecological habitat present	n/a	No comparable habitat with established critical load estimate available	n/a	n/a	n/a	n/a	n/a	n/a
Skipwith Common	European dry heaths	n/a	10	20.2	0.443	<1	20.2	202	Not Significant
	Northern Atlantic wet heaths with Erica tetralix	n/a	10	20.2	0.443	<1	20.2	202	Not Significant
Thorne Moor	Degraded raised bogs still capable of natural regeneration	n/a	5	20.7	0.0337	<1	20.7	415	Not Significant
Meadow East of Orchard Farm	Neutral grassland (Mountain Hay Meadows)	n/a	10	19.8	0.0407	<1	19.8	198	Not Significant

When considering the Nutrient nitrogen deposition associated with operating in Air mode, all PCs are less than the 1% screening threshold and hence the impact from the power station is deemed not significant at all sites and associated habitats listed.

Table 5.28 Predicted NOX at Ecological Receptors (Annual Mean) in Air-Mode combined with Auxiliary Boiler during start-up

Sites	**Critical Level**	**Background Conditions**	**PC (µg m^{-3})**	**PC/ AQS (%)**	**PEC (µg m^{-3})**	**PEC/AQS (%)**	**Significance**
	(µg m^{-3})	(µg m^{-3})					
Humber Estuary	30	18	0.16	<1	18.2	61	Not Significant
Lower Derwent Valley	30	12.8	0.253	<1	13.1	44	Not Significant
River Derwent	30	13.8	1.46	5	15.3	51	Acceptable
Skipwith Common	30	12.9	0.163	<1	13.2	44	Not Significant
Thorne Moor	30	14.9	0.136	<1	15.1	50	Not Significant
Meadow East of Orchard Farm	30	14.8	0.235	<1	15	50	Not Significant

When considering the predicted NOx concentrations associated with operating in Air mode, all PCs are less than the 1% screening threshold, except for the River Derwent (PC = 5% of AQS), however, the PEC represents 51% of the AQS and hence the impact from the power station is deemed not significant at all sites and associated habitats listed.

Table 5.29 Predicted NO_X at Ecological Receptors (24 hour Mean) in Air-Mode combined with Auxiliary Boiler during start-up

Sites	**Critical Level**	**Background Conditions**	**PC (µg m^{-3})**	**PC/AQS (%)**	**PEC (µg m^{-3})**	**PEC/AQS (%)**	**Significance**
	(µg m^{-3})	(µg m^{-3})					
Humber Estuary	75	36	3.06	4	39	52	Not Significant
Lower Derwent Valley	75	25.6	3.55	5	29.1	39	Not Significant
River Derwent	75	27.6	15.6	21	43.2	58	Acceptable
Skipwith Common	75	25.9	3.38	5	29.3	39	Not Significant
Thorne Moor	75	29.8	2.52	3	32.3	43	Not Significant
Meadow East of Orchard Farm	75	29.8	9.39	13	39.1	52	Acceptable

When considering the predicted NOx concentrations (24hr mean) associated with operating in Air mode combined with auxiliary boiler during start-up, all PCs are less than the 1% screening threshold, except for the River Derwent (PC = 5% of AQS), however, the PEC represents 51% of the AQS and hence the impact from the power station is deemed not significant at all sites and associated habitats listed.

Table 5.30 Predicted SO_2 at Ecological Receptors (Annual Mean) in Air-Mode combined with Auxiliary Boiler during start-up

Sites	Critical Level (µg m^{-3})	Background Conditions (µg m^{-3})	PC (µg m^{-3})	PC/ AQS (%)	PEC (µg m^{-3})	PEC/AQS (%)	Significance
Humber Estuary	10	5.39	0.259	3	5.65	56	Acceptable
Lower Derwent Valley	10	5.99	0.319	3	6.31	63	Acceptable
River Derwent	10	5.76	1.619	16	7.38	74	Not acceptable
Skipwith Common	10	6.75	0.288	3	7.04	70	Not acceptable
Thorne Moor	10	4.53	0.219	2	4.75	47	Acceptable
Meadow East of Orchard Farm	10	6.23	0.261	3	6.49	65	Acceptable

When considering the predicted SO2 concentrations (Annual mean) associated with operating in Air mode combined with auxiliary boiler during start-up, all PCs exceed the 1% screening threshold. The PECs exceed the 70% screening threshold at the River Derwent and also at Skipwith Common. The PEC at the Skipwith Common fractionally exceeds the 70% threshold with the background concentration significantly dominating the PEC (95.9%). The River Derwent is significantly closer to the site resulting in a greater PC of 16% of the AQS. The PEC exceeds the 70% threshold by 4% with the background again dominating the PEC (78%). The modelling of emissions in air mode is based on the assumption that the plant will operate for 100% of the year, following the commissioning phase of the project, this would not occur and indeed operation in air mode would be restricted by the Emissions Performance Standard.

6.0 BAT STATEMENT REGARDING EMISSIONS TO AIR

Currently there is no established BAT framework or definition for CCS plants, post-capture, pre-capture or Oxyfuel technology. It is acknowledged that the definition of BAT would require technology to be commercially available and proven, however, the purpose of the White Rose CCS project is to demonstrate the technology in the first instance and hence BAT criteria are emerging for the associated technologies in terms of CCS plants. It is believed that as CCS projects are developed, then BAT criteria will be further defined.

When considering the emissions from the power plant in Air mode and Oxy mode, it is important to note the fundamental differences in the volume of flue gas and the quality and composition of flue gas and indeed the reasons for these differences. In terms of comparing the emissions in both modes of operation, it is also necessary to define and compare the impacts of operating in these modes. In terms of the common pollutants, operation in oxy mode demonstrates a lesser impact than operating in air mode. Also, as defined previously, comparing emissions from CCS technologies and specifically oxyfuel technology to defined emissions limits is not a reasonable or accurate methodology of defining impacts. One of the main drivers for the difference in mass emissions is the CO_2 specification required by the transport and storage provider, for example, high purity CO_2 which results in an iterative process of recycling a proportion of the flue gas and hence generating a purer CO_2 stream.

The design of the White Rose CCS plant is considered state of the art and represents the cutting edge of oxyfuel technology. The challenge for any relatively new technology entering the energy industry is to achieve the following requirements:

- New generation capacity is required to be low carbon and this is driven by the Emissions Performance Standard
- Flexibility and ability to meet the changing demands of the future energy market
- Comparable and competitive cost of electricity in line with other low carbon generation technologies

When considering the emissions and impacts of the plant operating in Oxy mode there is a single impact resulting in an unacceptable impact which is identified in table 6.6. Emissions of Chromium (VI) generates a PC of 6.15% and a PEC of 81%. As previously explained, the modelling of Chromium (VI) is based on a number of assumptions, however, these assumptions are believed to be very conservative in terms of estimation of total chromium being chromium (VI). In addition, the background concentration applied dominates the PEC and indeed would exceed the 70% screening threshold although the air quality standard is not breached. Since each and every other emission screens out and no significant impact is identified applying the Agency's H1 assessment criteria, then it is evident that in terms of atmospheric emissions, the plant when operating in Oxy mode would represent BAT.

Previous discussions with the Agency have defined operation in Air mode as not normal operation. Ideally the plant would only operate in Air mode in the event that a fault or a breakdown prevented the plant from moving into operation in Oxy mode. Operation in Air mode has been modelled assuming continuous operation for 8,760 hours. Consideration of the specific emissions generated in Air mode show a small number of emissions which do not immediately screen out when applying the Agency's H1 criteria. These emissions include SO_2 (15 minute mean), although the operation of the power plant would not result in the air quality standard being breached, indeed the PEC for this criterion is only 25% of the AQS. Again, Chromium (VI) levels are deemed not acceptable, however, the same rationale applies as identified above with the background Chromium (VI) level being greater than 70% of the AQS.

Other modelled impacts include an exceedance of the 1% critical load screening threshold on the Humber estuary, Skipwith Common and Thorne Moor for acid deposition. In all instances the critical load for each of the habitats is already exceeded significantly. When considering the PC against the background deposition rates, the results range from 1.48% through to 2.5% demonstrating the low process contributions compared to the backgrounds. In addition, when reviewing the citations for each of the relevant habitats where the PC exceeds 1% of the critical load, the citations do not allude to the impact from air pollution in terms of the habitats being impacted or not recovering. Indeed most of the SSSI units appear to be recovering despite the fact that the critical load is exceeded.

From a permitting perspective, it has been proposed that the Agency may wish to consider permitting the operations in Air mode as a standard power station, i.e. compliance with a concentration limit. However, operation in Oxy mode would require a different metric since it is not feasible to normalise emissions. It has been proposed that a metric of mass per unit of electricity generated would be more appropriate due to the physical nature of the flue gas generated in Oxy mode operation.

7.0 POLICY CONTEXT

Air Quality Standards and Guidelines for Human Health

Within the UK the majority of the air quality standards relating to ambient air quality are based upon the European Union Air Quality Standards(9). The EU air quality standards relate to the following pollutants, pertinent to this assessment:

- Arsenic (As);
- benzene (one of few VOCs specifically regulated);
- cadmium (Cd);
- carbon monoxide (CO);
- lead (Pb);
- nickel (Ni);
- nitrogen dioxide (NO_2);
- PM_{10};
- $PM_{2.5}$; and
- sulphur dioxide (SO_2).

The *Air Quality Standards Regulations 2010*(10) implements the *Air Quality Framework Directive* and its four *Daughter Directives*. These regulations have been implemented through the *Air Quality Strategy for England Wales, Scotland and Northern Ireland 2007* (AQS)(11).

The AQS also sets out a framework for addressing emissions of pollutants not currently included in the EU and UK air quality standards. In the UK, there are a variety of air quality guidelines which are used to assess the potential impacts of pollutants not included in the EU and UK air quality standards and which are derived from sources, including:

- Guidelines developed by the Expert Panel on Air Quality Standards (EPAQS)(12); and
- Guidelines derived from UK occupational exposure standards and from the World Health Organisation, as presented in the Environment Agency's Guidance Note H1(13).

The numerical values and averaging periods are discussed in *Section 2.2*.

Air Quality Standards and Guidelines for Ecology

In addition to undertaking an assessment of the potential impacts of emissions from the facility on human health, assessment of air quality impacts on protected ecological receptors has also been undertaken. Impacts at sensitive ecological receptors primarily arise as a result of pollutant emissions by the following mechanisms:

- direct impacts on flora due to increased concentrations of airborne pollutants;

(9) European Union (accessed April 2014) Air Quality Standards http://ec.europa.eu/environment/air/quality/standards.htm
(10) The Air Quality Standards Regulations 2010 Statutory Instrument 2008/301 http://www.legislation.gov.uk/uksi/2010/1001/contents/made
(11) Defra (2007) The Air Quality Strategy for England, Scotland, Wales and Northern Ireland http://www.defra.gov.uk/environment/quality/air/airquality/strategy/documents/air-qualitystrategy-vol1.pdf
(12) Department of the Environment, Food and Rural Affairs, Expert Panel on Air Quality Standards http://www.defra.gov.uk/environment/quality/air/airquality/panels/aqs/
(13) The Environment Agency for England and Wales (2010) Horizontal Guidance Note H1: *Annex F*

- indirect impacts on flora due to changes in soil chemistry brought about by deposition of pollutants to soil; and

- impacts on fauna due to changes in flora.

The *European Habitats Directive*(14) sets out the legal framework requiring EU member states to protect habitat sites supporting vulnerable and protected species, as listed within the Directive. This Directive was incorporated into UK domestic legislation by means of the *Conservation of Habitats and Species Regulations 2010*(15). This Directive requires the protection of certain sites including Special Areas of Conservation (SACs), Special Protection Areas (SPAs) and Ramsar sites. In addition, within this air quality assessment, consideration is also made of impacts on nationally important ecology sites in the form of Sites of Special Scientific Interest (SSSIs) and any relevant locally designated habitat sites.

The relevant standards and guidelines for assessing impacts to sensitive ecological receptors are derived from a number of sources:

- air quality standards for oxides of nitrogen (NO_x) and sulphur dioxide (SO_2) for the protection of habitats are derived from European Union Air Quality Standards and are included in the AQS;
- air quality guidelines for ammonia (NH_3), NO_x (24 hour mean) and hydrogen fluoride (HF) have been derived by the Centre for Ecology and Hydrology (CEH) and are set out in the Environment Agency's H1 Annex F – Air Emissions[16]; and

- guidelines for the assessment of acid and nutrient nitrogen deposition have been derived according to habitat type, and are set out on the Air Pollution Information System (APIS) website(17).

On the basis of the above legislative framework and guidance, relevant critical levels (that relate to airborne pollutants) and site specific critical loads (that relate to deposition of materials to soils) have been established. These values represent the relevant environmental criteria for this assessment.

Industrial Emissions Directive (IED)

In the European Union, the IED applies to industrial processes meeting certain capacity requirements. Of particular interest in this assessment are the emission limits (in terms of emission concentrations) that are set out in the IED, as the direct replacement for the Large Combustion Plant Directive.

The emission limits set out in IED for coal fired power plants have been used in the assessment as the benchmark for the Project, but it must be noted that these have been set for a standard coal-fired power plant, which has a considerably different emissions profile. Most critically, a standard coal fired plant has a higher volume flow rate, and therefore, when operating in oxy-mode, combustion derived pollutants are less diluted and hence concentrations in emissions to air are higher than would be the case for a standard coal fired power plant utilising the same air quality abatement technology.

(14) Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora
(15) Statutory Instrument 2010 No. 490 The Conservation of Habitats and Species Regulations 2010
[16] Environment Agency (EA) H1 Annex F – Air Emissions v 2.2 December 2011

(17) Centre for Ecology and Hydrology (2010) UK Air Pollution Information Service http://www.apis.ac.uk/

Local Air Quality Management

The Environment Act 1995 requires local authorities to periodically review and assess air quality. Initially, a screening process was undertaken by local authorities to identify which pollutants, of the eight in the AQS at the time of the screening process, may be in excess of the air quality standards. Where pollutant concentrations were identified to be in excess of the standards, local authorities undertook a further investigation to identify exactly where standards were exceeded. On the basis of the results of this investigation, Air Quality Management Areas (AQMAs) were declared for the relevant locations and local authorities have developed Air Quality Management Plans setting out measures that will be taken to improve air quality in these AQMAs.

Following this initial staged process, there is an on-going review and assessment process, which periodically reviews local air quality, with regard to changes that may cause impacts on the local air quality. These might include: new roads; changes in road layouts; other new development; new industry, closure or changes in existing industry, etc. On the basis of this on-going process, local authorities may declare or revoke AQMAs and update action plans accordingly.

Where appropriate, AQMAs in the vicinity of the Project have been considered and local air quality management reports have been used to inform the baseline air quality.

Environmental Protection Act 1990

The Environmental Protection Act 1990 (EPA 1990) states:

"Subject to subsections below, the following matters constitute 'statutory nuisances' for the purposes of this Part, that is to say—

a) any premises in such a state as to be prejudicial to health or a nuisance;
b) smoke emitted from premises so as to be prejudicial to health or a nuisance;
c) fumes or gases emitted from premises so as to be prejudicial to health or a nuisance;
d) any dust, steam, smell or other effluvia arising on industrial, trade or business premises and being prejudicial to health or a nuisance;
e) any accumulation or deposit which is prejudicial to health or a nuisance;
f) any animal kept in such a place or manner as to be prejudicial to health or a nuisance;
g) (fa) any insects emanating from relevant industrial, trade or business premises and being prejudicial to health or a nuisance;
h) (fb) artificial light emitted from premises so as to be prejudicial to health or a nuisance;
i) noise emitted from premises so as to be prejudicial to health or a nuisance;
j) (ga) noise that is prejudicial to health or a nuisance and is emitted from or caused by a vehicle, machinery or equipment in a street or in Scotland, road; and
k) any other matter declared by any enactment to be a statutory nuisance."

Pertinent to this assessment, EPA 1990 requires the control of emissions of dust that may arise from the construction or operation of the Project, such that these emissions do not result in nuisance issues.

Key considerations when assessing impacts

The emissions characteristics of the OPP in air-mode and oxy-mode are fundamentally different both in the flue gas composition and volumes. In oxy-mode the volume of flue gas is considerably lower due to the removal of nitrogen from the combustion air and carbon dioxide from the flue gas. In addition, with the specification of capture gas specified by National Grid Carbon, the composition of flue gas in oxy-mode is significantly different to that in air-mode.

During oxy-mode, there is a drying process whereby water vapour is removed from the captured gas, this process requires the captured gas to pass through drying beds which are regenerated on a regular 8 hour cycle. The regeneration cycle occurs once every 8 hours and leads to a short increase in emissions.

The final group of emissions identified as having an unacceptable impact are SO2 concentrations at various habitat sites, specifically the River Derwent and Skipwith Common. Again, the background concentrations dominate the PEC. The PEC for the River Derwent exceeds the 70% screening threshold by 4% but does not breach the Air Quality Standard. The PEC for Skipwith Common exceeds the 70% screening threshold limit by 0.38%.