



**Variation to Operate Carbon Capture and Directly Associated Activities to on Unit 2 and/or Unit 1 at Drax Power Station (VP3530LS) Supplemental Information Provision**

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## Glossary

AGL	Above Ground Level
AQAL	Air Quality Assessment Level
AQMA	Air Quality Management Areas
ASR	Air Quality Annual Status Report
BAT	Best Available Techniques
BREF	Large Combustion Plant Best Available Techniques Conclusion Reference document
CCC	Committee on Climate Change
CEM	Continuous Emission Monitors
CERC	Cambridge Environmental Research Consultants
DCO	Development Consent Order
EA	Environment Agency
EAL	Environmental Assessment Levels
ELV	Emission Limit Values
EQS	Environmental Quality Standards
ESP	Electrostatic Precipitators
FGD	Flue Gas Desulphurisation
HSS	Heat Stable Salts
IED	Industrial Emissions Directive
KM-CDR	Kansai Mitsubishi Carbon Dioxide Recovery Process
LCP	Large Combustion plant
Main Stack	The main stack at the Site
MHI	Mitsubishi Heavy Industries
OTNOC	Other than Normal Operating Conditions
PCC	Post-combustion carbon dioxide capture
PC	Process Contribution
PEC	Predicted Environmental Concentration
PFA	Pulverised Fly Ash
REACH	Registration Evaluation and Authorisation of Chemicals
SDC	Selby District Council

Site	Drax Power Station
SNCR	Selective Non-Catalytic Reduction

# Variation to Operate Carbon Capture and Directly Associated Activities on Unit 2 and/or Unit 1 at Drax Power Station (VP3530LS) Supplement Information Provision

## 1.0 Introduction

The agreed 'Staged' application process identified several areas where additional information was required and an expected timetable and initial submission of [August 2022] that information would be provided. This further variation application provides the supplemental information required in the areas which are not directly impacted by the interface with the transport and storage system irrespective of data.

Two the elements directly related to the transport and storage system, and so additional information cannot be provided at a suitable level of detail until additional information is made available by the operating company of the system. Because of this interface Drax request that these elements are addressed within the determination phase of the variation process, namely details of the compression system and associated venting.

Additionally, this document also provides supplemental information irrespective of data previously supplied where more precise information can be given due to the progression of the project and associated work streams. Areas that specifically need to be updated are minor technical adjustments to the air quality modelling assessment, considerations around the post PCC flue gas reference monitoring conditions and an update to the proposed emission limit values for the post PCC flue gases

## 2.0 Release to air - further information

The combination of biogenic generation with carbon capture at a commercial scale has not been undertaken before. However, carbon capture is a mature well understood technology with PCC previously achieved at commercial scale for coal powered stations.

### 2.1 Biomass combustion Flue Gas and PCC operations

As previously mentioned, PCC in combination with coal has been demonstrated at commercial scale internationally and PCC in combination with biomass combustion is similar and so is technologically feasible. Additionally, biomass combustion has several critical benefits in relation to its flue gas over that of other solid fuels.; as set out in paragraphs 3.1.1 -3.1.3 below.

#### 2.1.1 Oxides of Nitrogen

Oxides of Nitrogen (NO<sub>x</sub>), specifically Nitrogen Dioxide, can react in specific conditions with amines to form nitrosamine and nitramine reaction products. Biomass combustion produces less NO<sub>x</sub> than other solid fuel due to it specific physiochemical properties, thereby reducing, the potential for the formation of reaction products compared to coal.

#### 2.1.2 Sulphur Oxides (SO<sub>2</sub>/SO<sub>3</sub>)

The majority of biomass fuels are naturally low in sulphur relative to coal. Given that all the sulphur within the combustion zone is fuel based this equates very low sulphur dioxide formation. Therefore, as the SO<sub>3</sub> is a small proportion of the total SO<sub>2</sub> this equates to very low SO<sub>3</sub> levels. SO<sub>3</sub> is a critical

species requiring control, to mitigate potential interactions with the amine-based solvent. Thus, the naturally low levels of sulphur oxides make control effective and as such reduce the associated risk of the solvent interaction.

### 2.1.3 Consistency

In addition to the lower levels of several key gases within the flue gas, woody biomass as a fuel is far more consistent than most other solid fuel in terms of its physical and chemical properties. This aids the control of these parameters as outlined in our previous submission.

## 2.2 Biomass combustion flue gas data

To support the position around biomass and the nature of their flue gases, Drax have undertaken a review of emissions emitted from the station from both coal and biomass. This enables a direct comparison of the flue gases to support the entrained benefits that come from using a biomass host unit for PCC. The results of this review are shown in **Table 1 to 3**.

The data clearly demonstrates the significantly reduced emission for NO<sub>x</sub>, SO<sub>2</sub> and particulate matter from biomass compared to equivalent units firing coal. Thus, the risk associated with any interactions between the amine and flue gases is also reduced by an equivalent factor.

The data provided included operations pre-Annex V and BAT conclusions and except for 99<sup>th</sup> percentile NO<sub>x</sub> and particulate matter is within the FEED envelope provided to MHI. Given the reduction in limits imposed by the BAT conclusions Drax are comfortable that our emissions are now within the provided envelope used to develop the design and associated emission releases.

**Table 1 – Biomass and Coal Emissions 2016 to 2022 NO<sub>x</sub> mg/Nm<sup>3</sup>.**

	Average	P50	P90	P99
<i>Biomass</i>	134.01	138.00	180.95	265.37
<i>Coal</i>	326.99	321.75	433.64	551.36

**Table 2 – Biomass and Coal Emissions 2016 to 2022 SO<sub>2</sub> mg/Nm<sup>3</sup>.**

	Average	P50	P90	P99
<i>Biomass</i>	18.08	17.50	46.40	92.48
<i>Coal</i>	311.58	265.09	517.68	1386.92

**Table 3 – Biomass and Coal Emissions 2016 to 2022 Total Particulate Matter mg/Nm<sup>3</sup>.**

	Average	P50	P90	P99
<i>Biomass</i>	3.97	5.74	14.48	27.36
<i>Coal</i>	12.61	9.89	24.30	46.82

## 2.3 Flue gas design parameters being utilised by FEED

To ensure that the absorber design was optimised to work with the host biomass units the PCC supplier was provided actual emissions data coupled with a maximum flue gas composition for the operation envelope for which the absorber had to operate from both an emission and capture efficiency position. The flue gas parameters provided for the FEED process on which the design, associated best available techniques and proposed emission limits are based are shown in **Table 4**



This data was utilised by MHI to develop the emission data for the process, through a combination of experience, process chemical engineering, modelling and trial data. The subsequent emission levels were then used to develop the emission position for both the modelling and the emission limit values within the variation application.

**Table 4 – FEED emission design parameters.**

<i>Trace components</i>	<b>Units</b>	<b>Test Data<sup>[1]</sup></b>	<b>P10<sup>[2]</sup></b>	<b>P50<sup>[2]</sup></b>	<b>P90<sup>[2]</sup></b>	<b>P99<sup>[2]</sup></b>
<i>CO</i>	ppmv (wet)	78.33	10.56	46.09	155.35	508.65
<i>NO</i>	ppmv (wet)	91.02	61.23	68.57	77.31	92.92
<i>NO<sub>2</sub></i>	ppmv (wet)	0.85	0	0	3.73	4.70
<i>N<sub>2</sub>O</i>	ppmv (wet)	0.01	0.00	0.00	0.00	0.40
<i>SO<sub>2</sub></i>	ppmv (wet)	11.57	3.20	11.03	25.41	44.89
<i>SO<sub>3</sub></i>	ppmv (wet)	0.11	0.03	0.10	0.23	0.41
<i>HCl</i>	ppmv (wet)	1.69	1.28	3.06	5.24	7.85
<i>NH<sub>3</sub></i>	ppmv (wet)	0.004	5.000			
<i>PM</i>	mg/Nm <sup>3</sup>	4.79	3.93	8.32	16.85	23.82
<i>Carbon in Fly Ash (pre Precip)</i>	%	6.46	3.97	6.63	10.51	15.01
<i>PM<sub>2.5</sub> Distribution</i>	>PM <sub>10</sub> (>10µm)	18.40				
	<PM <sub>10</sub> (<10µm)	81.60				
	<PM <sub>2.5</sub> (<2.5µm)	61.60				

## 2.4 Emission testing data for suitable comparator plant

The partnership of carbon dioxide capture and bioenergy generation is an emerging technology pairing that is critical to achieving the UK government’s net zero target for the UK’s 2050 Net Zero target and ambition to achieve 5Mt per annum of carbon dioxide removals by 2030. This position is supported by the recent Committee for Climate Changes report on delivering a reliable decarbonised power generation system (Climate Change Committee, 2023).

As a first of a kind emission data from carbon capture with bioenergy is limited, which is further compounded when trying to provide evidence specific to proprietary solvents and PCC technologies. Although specific data is limited, there is data relating to the solvent in relation to other solid fuel firing, such as coal. This is important as solid fuels generate a different composition of flue gases over

that of gas fired plant which include more constituents that of relevance to amine-based carbon dioxide capture such as CO<sub>2</sub> levels, NO<sub>x</sub> and SO<sub>2</sub>.

This data can be compared to that of biomass if the differences in primary species emissions are accounted for and factored into assessments and assumptions. For example, where coal data is available, higher levels of NO<sub>2</sub> and SO<sub>x</sub> will generally result in high levels of degradation and vapour formation compared to biomass generation, where these species are generally significantly lower.

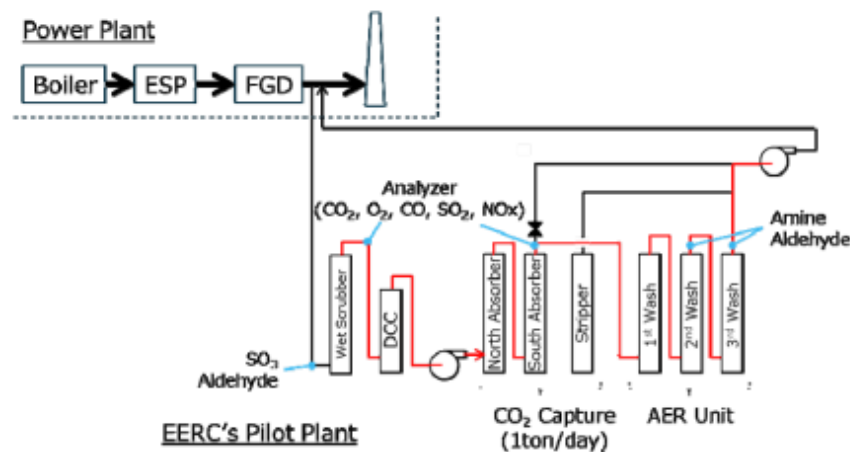
It is on this basis for the data available from trials, that those undertaken on coal are the more directly comparable with a biomass plant in terms of results, factoring for NO<sub>x</sub> and SO<sub>2</sub> levels within the flue gas when assessing the trial results.

### 2.4.1 Coal with KS21™ Carbon Capture Trial

The trial took place at a power station in the USA with a proportion of the flue gas transferred to the trial plant before being returned to the main stack as shown in **Figure 1**. The influent flue gas was treated using only electrostatic precipitators and flue gas desulphurisation of the flue gas before the trial plant for carbon capture. The NO<sub>x</sub> emissions from coal generation are higher than those from a biomass plant, so the potential associated degradation for NO<sub>2</sub> would be greater by comparison. The coal station source fuel for the trial was lignite, likely a lower sulphur<1% lignite fuel.

Two tests run of duplicate samples were undertaken after 408 operational hour and 432 hours respectively, using the JIS K 0099 gas absorption method. The inlet and exit temperature of the absorber flue gas were broadly consistent with the envelope of the Drax PCC.

**Figure 1 – block diagram of carbon capture trial layout.**



**Fig. 3.17 System configuration of pilot test facility in North Dakota**

The emissions suite (targeted primary and secondary amines) only identified one emitted substance from the trial. The identified emission substance was a secondary amine in 2-(Ethylamino)Ethanol. The maximum release was 0.21mg/m<sup>3</sup>. All the other species tested were below the limit of detection for the sampling and analytical method.

## 2.4.2 Solvent Contact Trial

As discussed previously, a MHI solvent contact trial was undertaken on the site between X and Y. This trial utilised a very small volume (65Nm<sup>3</sup>/h) of flue gas from biomass unit 1 and 2, to come in to contact with the KS21™ solvent to understand the long-term lifecycle of the solvent when in contact with the biomass flue gas. This contact information to support the solvent life elements of the larger plant.

Although the primary purpose of the trial was a study of the solvent and how long-term exposure to the flue gas would affect the solvent, some emissions testing was undertaken.

The tests, due to the size of the pipework, cannot be taken as directly representative of larger scale operations due to oversampling (ie all the gas stream was taken, low temperatures involved etc) and the trial plant does not incorporate all the control techniques that the larger PCC system is designed to deploy in control of emissions (e.g demisters, quencher, acid wash)

The emission trial utilised the JIS K 0099 (Gas Absorption) test method. The initial testing was carried out after only 100hr of running, for which again only 2-(Ethylamino)Ethanol was detected at a level of 0.14mg/m<sup>3</sup>. A further suite of tests was undertaken but the data analysis for these samples has not yet been concluded at the time of writing.

## 2.5 Emission testing data from other trials

MHI has undertaken further testing of the KS21™ solvent at the Technology Centre in Mongstad, Norway. The testing here utilised flue gases from several sources, with the majority of the trials conducted on a low concentration CO<sub>2</sub> flue gas from a gas-fired source, which due to the low CO<sub>2</sub> levels and different composition is not directly comparable to biomass flue gases.

As per the trial 3.4 above, the trial did not include all the control technology that our PCC system will use for example demisters, acid wash. Although the trial incorporates two levels of water wash, these did not incorporate any demister solutions and so increased the risk of mechanical entrainment of droplets due to the sampling technique being used. Thereby risking higher results than typically would be expected.

The testing also undertaken utilised a different sampling methodology than the previous JIS K 0099 testing, which was more sensitive to droplet carry over. The sampling was an isokinetic based sample with an impinger train containing a suitable sampling solution. This was then analysed using a non-ISO, none ISO17025 LC MS QQQ methodology.

### 2.5.1 Comparison review

Given that the testing was based on gas consumption with a lower CO<sub>2</sub> percentage and without demisters above the water wash levels it is not felt that the trial and associated results are comparable to what would be expected from the PCC system to be built on Site. By contrast the site solution has up to four levels of demisters, up to three levels of water wash and a final acid wash section.

The lack of these elements in the trial when coupled with the test methods, embed a degree of uncertainty within the results. Additionally, there was only a single periodic test run undertaken during the trial, so it is difficult to draw any real conclusions from the data.

## 2.5.2 Conclusions

Although, it is felt that the testing at Mongstad was not directly comparable due to the fuel source and other process related elements, the results showed a total primary amine release of  $0.9\text{mg}/\text{m}^3$  with Ethylamine reported at  $0.9\text{mg}/\text{m}^3$ . Total secondary amine was reported at  $0.26\text{mg}/\text{m}^3$  with 2-(Ethylamino)Ethanol reported  $0.23\text{mg}/\text{m}^3$ . Total nitrosamines were reported at  $0.015\text{mg}/\text{m}^3$  a nitrosamine level higher than those expected from the PCC system to be installed. This on the basis that the inclusion of effective demisting of the flue gas stream at the back of the wash sections in the PCC system will reduce the vapour and mist from the flue gas stream. This then coupled with an acid wash section (specifically designed to target these emissions) is expected to reduce the emission in line with the worst case modelled levels in the first stage submission. Based on the above trial data additional sensitivity analysis was undertaken to understand the potential implication of these results is found in section 3.13.

## 2.6 Expected Emission species from the PCC process

Based on the data provided from the PCC manufacturer ,MHI, and reviewed by Drax and WSP, as per section 3.3 the following species are expected to be directly released to air:-

- Aldehydes
- Ammonia
- Primary Amines specifically Ethylamine
- Secondary Amines specifically 2-(Ethylamino)Ethanol
- Nitrosamines specifically N-Ethyl-N-(2-hydroxyethyl)nitrosamine
- Nitramines

Of these substances, the directly released nitrosamine is circa 1% of all the direct amine emissions. The majority of the short-lived nitrosamines are formed through secondary atmospheric reactions within the atmosphere, around 98% are formed this way. These atmospheric reactions continue with nitrosamine having half-lives of <1 day through photoreaction degradation (Nielsen, 2011).

## 2.7 Updated Proposed Air Emission Limit Values

The proposed point source emissions to air from the PCC process are based on the defined normal operating parameters (between 60 and 100% of flue gas volume from the host unit). These are shown in **Table 5** which has been updated in relation to  $\text{SO}_2$  in response to improvements associated with the quencher identified during FEED. The amine limits (typo correction of primary amines limit) are proposed on the basis of continuous emission monitoring being available. Should this not be available, periodic monitoring will be used and the proposed limits are provided in **Table 6**.

The host biomass units (IED, chapter 3 compliant LCPs) will continue to operate to the BREF based best available technique limits as agreed in variation 18 to the environment permit and shown in **Table 7**.

The emission limits are based on the data provide by MHI from the data provided around the current host unit flue gas composition.

**Table 5 – Proposed point source emission to air limits for the Carbon Capture process**

Species	Method	Monitoring Type	Proposed ELV		Units	Confidence internal (%)
			Daily	AEL		
<b>SO<sub>2</sub></b>	BS EN14181	Continuous	<b>74</b>	<b>45</b>	mg/Nm <sup>3</sup>	20
<b>Total Particulates</b>	BS EN14181	Continuous	16	10	mg/Nm <sup>3</sup>	30
<b>HCl</b>	BS EN14181	Continuous	25		mg/Nm <sup>3</sup>	40
<b>NH<sub>3</sub></b>	BS EN14181	Continuous		10	mg/Nm <sup>3</sup>	40
<b>Aldehyde</b>	BS EN14181	Continuous	10	7	mg/Nm <sup>3</sup>	40
<b>Total Primary Amine</b>		Continuous <sup>#</sup>	2	1	mg/Nm <sup>3</sup>	40
<b>Total Secondary Amine</b>		Continuous <sup>#</sup>	1	0.3	mg/Nm <sup>3</sup>	40
<b>HF</b>	CEN/TS 17340	Periodic		1	mg/Nm <sup>3</sup>	40
<p>Notes # the table assumes appropriate continuous emission monitors (CEMs) can be identified and certified for the monitoring of amines prior to operation. Where CEMs are not available periodic monitoring will be utilised.</p>						

**Table 6 – Proposed periodic amine point source emission to air limits for the Carbon Capture process**

Species	Method	Monitoring Type	Proposed ELV			Units	Confidence internal (%)
			Monthly	Average over sampling period	AEL		
<b>Aldehyde</b>	Adapted EN21877	Periodic (Quarterly, triplicate sampling)		7		mg/Nm <sup>3</sup>	To be determined based on sampling and analytical methods
<b>Total Primary Amine</b>	Adapted EN21877	Periodic (Quarterly, triplicate sampling)		2		mg/Nm <sup>3</sup>	
<b>Total Secondary Amine</b>	Adapted EN21877	Periodic (Quarterly, triplicate sampling)		1		mg/Nm <sup>3</sup>	

**Table 7 – Current point source emission to air limits for biomass combustion activity only**

Species	Method	Monitoring Type	Proposed ELV			Units	Confidence internal (%)
			Daily	Monthly	AEL		
<b>NO<sub>x</sub></b>	BS EN14181	Continuous	200	200	160	mg/Nm <sup>3</sup>	20
<b>SO<sub>2</sub></b>	BS EN14181	Continuous	165	200	100	mg/Nm <sup>3</sup>	20
<b>Total Particulates</b>	BS EN14181	Continuous	16	20	10	mg/Nm <sup>3</sup>	30
<b>HCl</b>	BS EN14181	Continuous	25			mg/Nm <sup>3</sup>	40
<b>Carbon Monoxide</b>	BS EN14181	Continuous			400	mg/Nm <sup>3</sup>	10
<b>HF</b>	CEN/TS 17340	Periodic			1	mg/Nm <sup>3</sup>	40
<b>HG</b>	BS EN13211	Periodic	25			µg/Nm <sup>3</sup>	

### 2.7.1 Nitramine and Nitrosamine Emissions

As part of the development of the variation application and this supplemental information, consideration has been given to the best available techniques involved in the control and monitoring of nitrosamines and nitramines. Drax is keen to ensure that it utilises the best available techniques in the mitigation and control of the formation and release of the substances directly from the PCC process.

It is Drax's view that the PCC process selected, in combination with the KS21 solvent, provides the best available technology in relation to mitigating and minimising the release of nitrosamine and nitramines. The modelling and data that Drax has provided as part of the permit variation application demonstrates this and shows that the robust technical solution we have proposed to minimise releases of these substances means that they will be released at lower concentrations than recently permitted non-proprietary solvents and below the detectable limits of currently approved testing and monitoring techniques. The technical solution includes, for example, multiple water wash levels partnered with demister technology, including specifically designed proprietary demisters and a final acid wash section with a combination of off the shelf and proprietary demister. The level of direct releases from the process used for the purposes of the air quality modelling provided as part of the permit application are based on the expected worst-case emissions when accounting for the highest permitted levels of substances that could react with solvent to form these substances under the current regulatory regime.

MHI has a long track record of developing the PCC process to reduce emissions, while reducing the electrical and heat demand required to capture carbon dioxide. However, as discussed previously the sampling and analysis of emissions of nitramines and nitrosamines was and continues to be challenging due to the low concentration of the substances in any emissions, many of which fall below levels of detectability or scientific accuracy. This is the case even in testing such as at TCM where the equipment used did not have the robust technological mitigations in place that our proposed project will have. This lack of appropriate testing and monitoring techniques continues to be a challenge for the industry, with research and development continuing to identify suitable sampling and analytical methods for these substances. We understand that the Environment Agency has recognised this issue and currently has projects in progress to resolve it.

Drax recognises that it is usual for an operator to propose an emission limit for the releases of Nitrosamines. However, any limit proposed must be capable of being monitored and enforced by the EA and so must align with accepted testing and monitoring techniques.

Drax is confident that the emissions levels of nitramines and nitrosamine as part of the permit application represents a worst-case scenario. However, currently certified sampling and analytical standards are not sufficiently refined to support the quantifications and set emissions limits that align to the modelling Drax has undertaken.

Whilst it would be possible for Drax to propose emissions limit values that align with currently unapproved testing and monitoring techniques, such a limit would substantially exceed the current modelled emissions. Drax recognises the current work of the EA to refine the techniques and expects suitable (and more granular) periodic and continuous emission monitoring standards to be available before the PCC units commence operating. Accordingly, Drax does not consider that at this stage proposing long-term emission limits for nitramine and nitrosamine releases at currently verifiable and approved levels of detection delivers the right balance between setting enforceable and detectable limits for the operator and providing the right level of regulatory rigour and oversight for the Environment Agency as the regulator.

Drax would welcome the view of the Environment Agency as to how best to approach this issue in the short term. However, Drax would propose that any approach taken on day 1 ELVs in relation to nitramines and nitrosamine is supported by an improvement condition that will align the requirements of the permit to updated testing and monitoring techniques as they are endorsed by the Environment Agency from time to time. In this regard, Drax is committed to undertaking a significant period and level of emission monitoring utilising the certified standards to seek to evidence the levels of emission from the PCC activity and confirm that the modelling was robust. Additionally, Drax is committed to utilising continuous emissions monitoring on the flue gas that exits the PCC activity and will aim to work with suppliers to develop and certify these instruments for nitrosamine and nitramine where required.

Drax believes that the approach outlined above is reasonable in light of the current uncertainty around limits of detection and testing standards and is consistent with what ought to be required when applying common sense as part of a “duly made” determination.

## **2.8 Proposed Periodic Monitoring Methods**

The testing of the aldehydes, primary amines, secondary amines will be based on EN21877 utilising an appropriate acidic impinger solution. The duration of the testing will be based on the advice provided by the analytic laboratories to support the analytic methods to be utilised in accordance with the appropriate standard.

## **2.9 Reference Condition Proposals**

Due to the reduction in flue volume by circa 13% through the absorption and removal of CO<sub>2</sub>, the reference monitoring conditions for the PCC process need to be developed. The current BAT guidance refers to the IED chapter III and LCP BREF BAT AELS at normalised conditions. Although understandable, the limits and reference conditions were developed for a different activity. Without adjustment the reference conditions this would result in a reduction to the BRef limits of host units with a PCC process in operation. This would place units operating PCC at a distinct disadvantage to those operating without PCC. This appears to be a well-meaning but unintended consequence of the guidance.

Due to this a review of the reference monitoring conditions post PCC is required; Drax suggest O<sub>2</sub> reference condition of 6.9% as per previous submission.

## 2.10 Air Quality Modelling Revision

An update to the air quality monitoring data has been made since our first submission due to several technical and project development that have been identified during our FEED works in relation to the sulphur dioxide abatement and the impacts of carbon dioxide removal from the gas stream.

In the original modelling, the annual and daily NO<sub>x</sub> emissions provided were based on the BAT-AEL of the host unit (160mg/Nm<sup>3</sup> Annual and 200mg/Nm<sup>3</sup> Daily) prior to the removal of the CO<sub>2</sub> from the exhaust gases. When accounting for the resultant gas volume change from the CO<sub>2</sub> removal the new concentrations would equate to 207mg/Nm<sup>3</sup> annual and 258mg/Nm<sup>3</sup> daily. This increase in concentration is purely due to the same mass of NO<sub>x</sub> being now mixed with a smaller volume of gas following the capture process. In effect this means that the mass of NO<sub>x</sub> will be unaffected by the carbon removal process and the mass emission rate in g/s from the PCC and merchant units will be identical.

Drax also proposes a reduction in the proposed BAT-AEL for SO<sub>2</sub> to 45mg/Nm<sup>3</sup> post the PCC process. This position has made possible through refinement and optimisation of the design of the quencher system during FEED.

To this regard the air quality modelling has been updated to reflect the changed emission levels and proposed levels shown in **Table 8**. This also includes a correction of an error within the equivalent table in the original submission in relation to amine 1 emissions. The updated modelling was done based on an emission of 1mg/Nm<sup>3</sup> not the 0.5mg/Nm<sup>3</sup> in the original table, aligning the modelling to the proposed emission limit value for primary amines.

In combination effect have been monitored and presented in the initial Variation Submission. Due to the uncertainty around what will and will not be constructed coupled with limited guidance we have provided a worst-case position for review.

**Table 8 – Updated Emission Parameters for the Baseline and With PCC Scenarios**

Parameter	Baseline (per Unit)	With PCC	
		With Scheme Scenario (per Unit <i>with</i> PCC)*	With Scheme Scenario (per Unit <i>without</i> PCC)**
No. Biomass Units	4	2	2
No. flues	2	1	1
Stack height (m agl)	259	259	259
Flue diameter (m)	8	8	8
Discharge Temp (°C)	144.2	80.0	144.2
Vol. flow (Nm <sup>3</sup> /s) <sup>(1)</sup>	573.0	444.5	573.0
Vol. flow (Am <sup>3</sup> /s) <sup>(2)</sup>	992.5	686.4	992.5



<b>NO<sub>x</sub> exit concentration (mg/Nm<sup>3</sup>)<sup>(3)</sup></b>	160	<b>207</b>	160
<b>NH<sub>3</sub> exit concentration (mg/Nm<sup>3</sup>)</b>	10	10	10
<b>Dust (PM<sub>10</sub>/PM<sub>2.5</sub>) exit concentration (mg/Nm<sup>3</sup>)<sup>(3)</sup></b>	10	10	10
<b>HCl exit concentration (mg/Nm<sup>3</sup>)<sup>(3)</sup></b>	5	5	5
<b>SO<sub>2</sub> exit concentration (mg/Nm<sup>3</sup>)<sup>(3)</sup></b>	100	45	100
<b>Amine 1 (Primary Amine) (mg/Nm<sup>3</sup>)<sup>(3), (4)</sup></b>	-	<b>1</b>	-
<b>Amine 2 (Secondary Amine) (mg/Nm<sup>3</sup>)<sup>(4)</sup></b>	-	0.3	-

Notes:  
 \* Applicable to Unit 1 & Unit 2 only (with CCS)  
 \*\* Applicable to Units 3 & Unit 4 only (without CCS)  
 (1) – Calculated at 273.15 Kelvin (0°C), pressure of 101.3 kPa, dry, 6% O<sub>2</sub>.  
 (2) – Actual discharge conditions, 4.9% H<sub>2</sub>O, 7.4% O<sub>2</sub>.  
 (3) – Representative of yearly average BAT-AELs. Corresponding daily average BAT-AELs.  
 (4) – Representative of proposed yearly average ELVs. Corresponding proposed daily average ELVs for amines provided in Appendix C. The proposed ELVs are more than the reasonable worst-case design emissions concentrations provided by the technology supplier (MHI).

### 2.10.1 Mass Emission Rates

**Table 9** below provides the exhaust parameters per unit for the units with and without carbon capture.

There are two units fitted with PCC and two units without PCC. There are two operational flues within the main stack and each flue, with diameter 8m, serves two units. **Table 10** provides the exhaust parameters per flue at full load i.e. two units with PCC, and two units without PCC. The gases from each unit merge within the flue and the combined exhaust is therefore simply calculated as double the emissions for a single unit (either with or without PCC). The parameters for the with PCC units in **Table 10** were used to model the mid-merit scenario when only two PCC units are operating.

When all units are operating at full load, the exhaust gases from the two flues are assumed, for modelling purposes, to merge on exit from the stack. **Table 11** shows the combined flue parameters used in the modelling. With PCC, the combined plume represented two units with PCC and two units without PCC; without PCC fitted, the combined plume represents four units without PCC. The methodology used to calculate the combined plume is set out below in steps 1 to 7.

It should be noted that all model runs, with the exception of those involving amines or cumulative impacts, were modelled using a 1g/s release rate and model results were scaled to the emission rates shown in **Tables 10 and 11** during post processing of results.

The pollutant emission rates are calculated as follows:

$$\text{Mass Emission Rate (g/s)} = \text{Concentration (mg/Nm}^3\text{)} \times \text{Volumetric Flow (Nm}^3\text{/s)} / 1000 \text{ (mg/g)}$$

**Table 9, Table 10 and Table 11** show the normalised flow rates, emission concentrations (ELVs) and calculated mass emission rates.

**Table 9 – Exhaust parameters per unit**

<i>Parameter</i>	<i>Per Unit</i>				
	<i>BECCS Unit (Inc Mitigation)</i>		<i>Biomass, No CCS Unit</i>		
<i>Flue Exit Temp (deg C)</i>	100		144.2		
<i>Flow Rate (m3/s, actual)</i>	725		993		
<i>Flow Rate (Nm3/s) (normalised to T,P)</i>	531		655		
<i>H2O (% , actual)</i>	4.9		10.8		
<i>O2 (% , actual)</i>	7.4		5.6		
<i>O2 (% , dry)</i>	7.8		6		
<i>Normal Flow Rate (Nm3/s) @ 6% O2, dry</i>	444		573		
		<i>mg/Nm<sup>3</sup></i>	<i>g/s</i>	<i>mg/Nm<sup>3</sup></i>	<i>g/s</i>
<i>NOx</i>	<i>Annual</i>	207	92.0	160	91.6
	<i>Daily</i>	258	114.7	200	114.5
<i>PM10</i>	<i>Annual</i>	10	4.44	10	5.73
	<i>Daily</i>	16	7.11	16	9.16
<i>NH3</i>	<i>Annual</i>	10	4.44	10	5.73
	<i>Daily</i>	10	4.44	10	5.73
<i>HCL</i>	<i>Annual</i>	5	2.22	5	2.86
	<i>Daily</i>	25	11.1	12	6.87
<i>SO2</i>	<i>Annual</i>	45	20.0	100	57.3
	<i>Daily</i>	215	95.6	215	123.1
<i>Amine 1</i>	<i>Annual</i>	1.0	0.444	-	
	<i>Daily</i>	2.0	0.889		
<i>Amine 2</i>	<i>Annual</i>	0.3	0.133		
	<i>Daily</i>	1.0	0.444		
<i>Nitrosamine 1</i>	<i>Annual</i>	0.0001	0.000044		
	<i>Daily</i>	0.0001	0.000044		
<i>Nitrosamine 2</i>	<i>Annual</i>	0.0001	0.000044		
	<i>Daily</i>	0.0001	0.000044		

**Table 10 – Exhaust parameters per flue**

<i>Parameter</i>	<i>Per Flue</i>				
	<i>2 x BECCS Units (Inc Mitigation)</i>		<i>2 x Biomass, No CCS Units</i>		
<i>Flue Exit Temp (deg C)</i>	100		144.2		
<i>Flow Rate (m3/s, actual)</i>	2 x 725 = 1450		2 x 993 = 1985		
<i>Flue Diameter (m)</i>	8		655		
<i>Exit Velocity (m/s)</i>	28.86		39.49		
<i>Normal Flow Rate (Nm3/s) @ 6% O2, dry</i>	2 x 444 = 889		2 x 573 = 1145		
	<i>mg/Nm<sup>3</sup></i>	<i>g/s</i>	<i>mg/Nm<sup>3</sup></i>	<i>g/s</i>	
<i>NOx</i>	Annual	207	183.3	160	183.3
	Daily	258	229.1	200	229.1
<i>PM10</i>	Annual	10	8.89	10	11.45
	Daily	16	14.22	16	18.33
<i>NH3</i>	Annual	10	8.89	10	11.45
	Daily	10	8.89	10	11.45
<i>HCL</i>	Annual	5	4.44	5	5.73
	Daily	25	22.2	12	13.75
<i>SO2</i>	Annual	45	40.0	100	114.5
	Daily	215	191.1	215	246.3
<i>Amine 1</i>	Annual	1.0	0.889	-	
	Daily	2.0	1.778		
<i>Amine 2</i>	Annual	0.3	0.267		
	Daily	1.0	0.889		
<i>Nitrosamine 1</i>	Annual	0.0001	0.000089		
	Daily	0.0001	0.000089		
<i>Nitrosamine 2</i>	Annual	0.0001	0.000089		
	Daily	0.0001	0.000089		

The combined exhaust parameters are provided above in **Table 11**.

The combined exhaust temperature has been calculated on the basis of a mass weighted average temperature. The calculation is as follows:

- Step 1:** The exhaust gas mass emission rate has been calculated using the ideal gas equation, the volumetric flow rate and the molecular weight of the exhaust gases (27.81g and 30.18g for the with PCC and without PCC units respectively)

Mass Release Rate (kg/s, per unit) =

$$\text{MW} \times \text{Pressure (100000 Pa)} \times \text{Volume Flow Rate (from Table 1)} /$$

$$R \text{ (Universal Gas Constant, 8.314)} \times T \text{ (Temperature, K, from Table 1)} \times 1000 \text{ (g/kg)}$$

$$= 27.81 \times 100000 \times 725 / (8.314 \times (273+100) \times 1000) = 650\text{kg/s (with CCS)}$$

$$= 30.18 \times 100000 \times 993 / (8.314 \times (273+144) \times 1000) = 864\text{kg/s (without CCS)}$$

**Step 2:** Calculate the mass weighted average temperature for 2 x PCC units and 2 x non PCC units

Mass weighted average Temperature (deg C) =

$$(2 \times 650 \times (273+100) + 2 \times 864 \times (273+144)) / (2 \times 650 + 2 \times 864) - 273.$$
$$= 125.2 \text{ }^{\circ}\text{C}$$

The combined volume flow of the exhaust is calculated by summing the volume flow rate from each unit, after adjustment to the mass weighted average temperature.

**Step 3:** Adjust the volume flow rate from the PCC and non-PCC units to the combined exhaust temperature

$$\text{PCC Unit @ } 125.2 \text{ }^{\circ}\text{C} = 725 \times (273 + 125.2) / (273 + 100) = 774 \text{ m}^3/\text{s}$$

$$\text{Non-PCC Unit @ } 125.2 \text{ }^{\circ}\text{C} = 993 \times (273 + 125.2) / (273 + 144) = 947 \text{ m}^3/\text{s}$$

**Step 4:** Sum the adjusted volume flow rates for 2 x PCC units and 2 x non-PCC units

$$\text{Total Combined Volume Flow} = 2 \times 774 + 2 \times 947 = 3443 \text{ m}^3/\text{s}$$

The effective diameter of the combined exhaust is the diameter giving a circular cross-section with the same area as the two 8m flues.

**Step 5:** Calculate the combined area of the 2 x 8m flues

$$\text{Combined Area} = 2 \times \text{Pi} \times \text{Radius}^2$$
$$= 2 \times 3.14 \times (8 / 2)^2 = 100.53 \text{ m}^2$$

**Step 6:** Calculate the equivalent diameter of a circular flue with the combined area

$$\text{Effective Diameter} = 2 \times \sqrt{(100.53 / \text{Pi})}$$
$$= 11.31 \text{ m}$$

The velocity of the combined exhaust is calculated from the combined volume flow and the effective stack

**Step 7:** Exit velocity

$$= \text{Combined Volume Flow} / \text{Effective Stack Area}$$
$$= 3443 \text{ m}^3/\text{s} / 100.53 \text{ m}^2$$
$$= 34.4 \text{ m/s}$$

The existing plumes can readily be seen to merge on exit from the individual flues within the common wind shield of the main stack at Drax. It is concluded that the plumes from the PCC and non-PCC units will also likely merge on exit from the stack since the temperature and volumetric flow rates of the individual flues vary only slightly from the combined flow (by approximately +/-7% and +/-15% respectively). As such, it is appropriate to model a combined exhaust for both existing and future operational scenarios.

**Table 11 – Exhaust parameters per combined exhaust**

<i>Parameter</i>	<b>Combined Exhaust</b>	
	<b>2 x Biomass Units with PCC 2 x Biomass Units, without PCC</b>	<b>4 x Biomass, No PCC</b>
<i>Flue Exit Temp (deg C)</i>	125.2	144.2
<i>Flow Rate (m3/s, actual)</i>	3443.3	3970
<i>Flue Diameter (m)</i>	11.3	11.3
<i>Exit Velocity (m/s)</i>	34.3	39.5
	<i>g/s</i>	<i>g/s</i>
<i>NOx</i>	Annual	366.5
	Daily	458.2
<i>PM10</i>	Annual	20.34
	Daily	32.55
<i>NH3</i>	Annual	20.34
	Daily	20.34
<i>HCL</i>	Annual	10.17
	Daily	36.0
<i>SO2</i>	Annual	154.5
	Daily	437.4
<i>Amine 1</i>	Annual	0.889
	Daily	1.778
<i>Amine 2</i>	Annual	0.267
	Daily	0.889
<i>Nitrosamine 1</i>	Annual	0.000089
	Daily	0.000089
<i>Nitrosamine 2</i>	Annual	0.000089
	Daily	0.000089

### 2.10.2 Amine Input parameters

The amine input parameters for the modelling amine chemistry module are provided below in **Table 12** and **Table 13** for the technology specific and sensitivity test analyses respectively.

Technology specific reaction rates were provided by the technology supplier (MHI). Other parameters were calculated using CERC Amine module guidance (specifically J(NO<sub>2</sub>) and OH constant).

The parameters for the sensitivity tests were based on parameters for MEA and DMA published in literature.

**Table 12 – Input parameters for technology-specific amine modelling**

<b>Parameter</b>	<b>Primary Amine</b>	<b>Secondary Amine</b>
<i>Amine/OH reaction rate constant</i>	0.74	1.97
<i>Amino radical/O2 reaction rate constant</i>	$2.37 \times 10^{-9}$	$2.37 \times 10^{-9}$
<i>Rate constant for formation of nitrosamine</i>	0.00468	0.00468
<i>Rate constant for formation of nitramine</i>	0.00789	0.00789
<i>Amine radical/NO2 reaction rate constant</i>	0.0175	0.0175
<i>Branching ratio for amine/OH reaction</i>	0.1	0.5
<i>Ratio of J(nitrosamine) to J(NO2)</i>	2016	0.34
	2017	0.34
	2018	0.33
	2019	0.32
	2020	0.32
<i>Constant for OH concentration calculations</i>	2016	0.00301
	2017	0.00284
	2018	0.00250
	2019	0.00257
	2020	0.00245
<i>Atmospheric oxygen concentration (ppb)</i>	209406000	209406000
<i>Creation of unstable nitrosamines</i>	No	No

**Table 13 – Input parameters (sensitivity testing) for technology-specific amine modelling**

<b>Parameter</b>		<b>MEA Tests</b>	<b>DMA Tests</b>
<i>Amine/OH reaction rate constant</i>	Low	1.72	1.41
	Mid	1.90	1.46
	High	2.07	1.50
<i>Amino radical/O2 reaction rate constant</i>	Low	$8.63 \times 10^{-8}$	$8.13 \times 10^{-8}$
	Mid	$4.44 \times 10^{-8}$	$4.19 \times 10^{-8}$
	High	$2.96 \times 10^{-9}$	$2.96 \times 10^{-9}$
<i>Rate constant for formation of nitrosamine</i>	Low	$1.28 \times 10^{-3}$	$1.82 \times 10^{-3}$
	Mid	$3.45 \times 10^{-3}$	$1.92 \times 10^{-3}$
	High	$5.42 \times 10^{-3}$	$1.92 \times 10^{-3}$
<i>Rate constant for formation of nitramine</i>	Low	$1.90 \times 10^{-4}$	$7.15 \times 10^{-3}$
	Mid	$3.70 \times 10^{-3}$	$7.15 \times 10^{-3}$
	High	$7.15 \times 10^{-3}$	$7.15 \times 10^{-3}$
<i>Amine radical/NO2 reaction rate constant</i>	Low	$5.00 \times 10^{-4}$	$1.45 \times 10^{-2}$
	Mid	$7.90 \times 10^{-3}$	$1.53 \times 10^{-2}$
	High	$1.50 \times 10^{-2}$	$1.60 \times 10^{-2}$
<i>Branching ratio for amine/OH reaction</i>	Low	0.05	0.380
	Mid	0.10	0.400
	High	0.15	0.420
<i>Ratio of J(nitrosamine) to J(NO2)</i>	Low	0	0.56
	Mid	0	0.41
	High	0	0.26

## 2.10.3 Building Data

The below **Tables 14 and 15** provide the details of the building used within the modelling.

**Table 14** below provides details of the buildings included in the modelling of Drax Power Station. All of the buildings are cooling towers on site (a northern block of six towers: 4A, 4B, 5A, 5B, 6A, 6B, and a southern block of six towers: CTS1 – CTS6) and represented as circular buildings in the modelling.

**Table 15** below provides details of the buildings included in the modelling of cumulative sources, namely Eggborough Power Station and Keadby Power Station. The buildings modelled at cumulative sources were limited to an additional 11 buildings over the Drax buildings since ADMS will only allow 25 discrete buildings to be modelled explicitly and the additional 11 buildings covered the principal buildings at Eggborough and Keadby.

**Table 14 – Modelled buildings at Drax Power Station (All Circular)**

<i>Name</i>	<i>Easting (m)</i>	<i>Northing (m)</i>	<i>Height (m agl)</i>	<i>Diameter (m)</i>
<i>CT4A</i>	466596.6	427571.8	114	95.6
<i>CT4B</i>	466464.1	427529.7		
<i>CT5A</i>	466326.6	427539.8		
<i>CT5B</i>	466219.1	427631.3		
<i>CT6A</i>	466351.3	427674.5		
<i>CT6B</i>	466490.2	427665.4		
<i>CTS1</i>	466175.4	426796.2		
<i>CTS2</i>	466306.7	426775.5		
<i>CTS3</i>	466097.8	426680.4		
<i>CTS4</i>	466117.2	426548.6		
<i>CTS5</i>	466254.5	426519.1		
<i>CTS6</i>	466327.3	426632.4		

**Table 15 – Modelled buildings at Eggborough and Keadby Power Stations (All Rectangular)**

<i>Name</i>	<i>Easting (m)</i>	<i>Northing (m)</i>	<i>Height (m)</i>	<i>Length (m)</i>	<i>Width (m)</i>	<i>Angle from North (deg)</i>
<i>Eggbgh_1</i>	457586	423905	50	63	28	119
<i>Eggbgh_2</i>	457650	423794	30	76	76	119
<i>Eggbgh_3</i>	457643	423923	50	63	28	119
<i>Eggbgh_4</i>	457665	423960	50	63	28	119
<i>Eggbgh_5</i>	457697	423905	30	49	134	119
<i>Eggbgh_6</i>	457541	423986	30	64	102	119
<i>Eggbgh_7</i>	457500	423910	30	35	54	119
<i>Keadby_1</i>	482676	411630	40	26.1	46.17	104
<i>Keadby_2</i>	482699	411676	30	47.3	19.9	104
<i>Keadby_3</i>	482630	411659	30	45.8	45.7	104
<i>Keadby_4</i>	481820	412158	90	13	40	0

## 2.11 Revised Human Health Modelling Results

The full set of NO<sub>2</sub> model results tables for the above scenarios have been updated due to the changes identified in 2.10 and are presented in the updated version of Appendix A.

The impact of the update to the NO<sub>x</sub> ELV set out in this submission is a slight increase in NO<sub>2</sub> concentrations with the PCC, but no change in the assessment of the significance of effect.

The modelled impacts for all assessed pollutants, including amines as MEA, are below 1% of the relevant AQALs, with the exception of the hourly mean data.

## 2.12 Revised Ecological Receptors Modelling Results

The tables below, show the original (August 2022 results) and revised (February 2023) maximum impacts of the PCC scheme on ecological receptors in response to the changes outline in 2.10. **Tables 16 and 17** show the impacts in relation to NO<sub>x</sub> and SO<sub>2</sub> concentrations and impacts on nitrogen and acid deposition.

The full set of modelled results tables have been updated and are presented in Appendix B (Operational Phase Air Quality Results Tables: Ecological Receptors).

In terms of NO<sub>x</sub> and SO<sub>2</sub> pollutant concentrations (and ammonia), the impacts of the Proposed PCC project in isolation will not result in significant air quality effects at assessed ecological receptors. As such, the text and conclusions remain from our initial submission unchanged following the design changes set out in 2.10 of this submission.

Similarly, the maximum impacts of the PCC project alone on nitrogen deposition are insignificant (<1% of the critical load) at all designated sites, even when taking into account the increased ELV for NO<sub>x</sub>.

The unmitigated impacts of the PCC project in isolation on acid deposition exceed 1% of the respective critical load at some sensitive habitats. The increase is largely imperceptible in the model results tables, with the exception being the maximum impact from the PCC project in isolation over Lower Derwent SAC and Brighton Meadows SSSI increasing from 2.0% of the critical load to 2.1% (**Table 16**). However, no additional designated sites have maximum impacts over 1% of the critical load over and above those identified in the first submission.

The reduction of SO<sub>2</sub> emissions detailed in above and modelled (see Appendix B for details) more than offsets this increase such that the maximum impact of the PCC project is ≤1% over all designated sites (**Table 17**).

Impacts under the PCC scenario are lower than for the baseline four-unit position. The results are however presented in Appendix B (Operational Phase Air Quality Results Tables: Ecological Receptors).

**Table 16 – Updated Emission Parameters**

Receptor	Annual Mean NO <sub>x</sub> (Max Impact as % of CL)		Daily Mean NO <sub>x</sub> (Max Impact as % of CL)		Annual Mean SO <sub>2</sub> (Max Impact as % of CL)	
	Air Quality ES	Feb 2023 Update	Air Quality ES	Feb 2023 Update	Air Quality ES	Feb 2023 Update
River Derwent SAC	0.3%	0.4%	1.1%	1.8%	0.2%	0.1%
Thorne Moor SAC/SPA/SSSI	0.2%	0.2%	0.6%	0.9%	0.1%	0.0%



Receptor	Annual Mean NOx (Max Impact as % of CL)		Daily Mean NOx (Max Impact as % of CL)		Annual Mean SO <sub>2</sub> (Max Impact as % of CL)	
	Air Quality ES	Feb 2023 Update	Air Quality ES	Feb 2023 Update	Air Quality ES	Feb 2023 Update
Lower Derwent SAC	0.3%	0.5%	0.4%	0.9%	0.2%	0.1%
Lower Derwent SPA	0.3%	0.5%	0.4%	0.9%	0.2%	0.1%
Skipwith Common SAC	0.1%	0.2%	0.3%	0.6%	0.1%	0.0%
Skipwith Common SSSI	0.1%	0.2%	0.3%	0.6%	0.1%	0.0%
Humber Estuary SAC	0.3%	0.4%	0.6%	1.2%	0.1%	0.1%
Humber Estuary SPA/SSSI	0.3%	0.4%	0.6%	1.2%	0.1%	0.1%
Brighton Meadows SSSI	0.3%	0.5%	0.4%	0.9%	0.2%	0.1%
Eskamhorn Meadows SSSI	0.1%	0.1%	1.3%	1.9%	0.0%	0.0%
Derwent Ings SSSI	0.3%	0.4%	0.4%	0.9%	0.1%	0.1%
Went Ings SSSI	0.1%	0.1%	0.3%	0.9%	0.0%	0.0%
Barn Hill Meadows SSSI	0.3%	0.4%	0.9%	1.7%	0.1%	0.1%
Burr Closes SSSI	0.1%	0.2%	0.5%	0.7%	0.1%	0.0%
Common Plantation SINC	0.0%	0.0%	0.6%	0.9%	0.0%	0.0%
Disused Railway Embankment SINC	0.1%	0.1%	1.0%	1.4%	0.0%	0.0%
Barmby-on-the-Marsh LWS	0.1%	0.2%	1.3%	1.9%	0.1%	0.1%
Brockholes SINC	0.0%	0.0%	1.1%	1.6%	0.0%	0.0%
Meadow East of Orchard Farm SINC	0.0%	0.0%	0.4%	0.5%	0.0%	0.0%
Barmby Pond LWS	0.2%	0.3%	0.9%	1.5%	0.1%	0.1%
Cobble Croft Wood SINC	0.1%	0.1%	0.6%	1.0%	0.0%	0.0%
Hagg Green Lane SINC	0.2%	0.3%	0.5%	1.1%	0.1%	0.1%

Receptor	Annual Mean NOx (Max Impact as % of CL)		Daily Mean NOx (Max Impact as % of CL)		Annual Mean SO <sub>2</sub> (Max Impact as % of CL)	
	Air Quality ES	Feb 2023 Update	Air Quality ES	Feb 2023 Update	Air Quality ES	Feb 2023 Update
Sand Pitt Wood & Barffs Close Plantation SINC	0.1%	0.1%	1.0%	1.4%	0.0%	0.0%
<b>Env. Agency Screening Criterion (as % of CL)</b>	<b>1%</b>		<b>10%</b>		<b>1%</b>	

Table 17 – Updated Emission Parameters

Receptor	Annual Mean N-Dep (Max Impact as % of CL)		Annual Mean Acid Dep (Max Impact as % of CL)	
	2022 ES	Feb 2023 Update	2022 ES	Feb 2023 Update
River Derwent SAC	Not assessed	0.4%	Not Sensitive	
Thorne Moor SAC	0.5%	0.5%	1.3%	1.3%
Thorne Moor SPA	0.2%	0.2%	Not Sensitive	
Thorne Moor SSSI	0.5%	0.5%	1.3%	1.3%
Lower Derwent SAC	0.3%	0.3%	2.0%	2.1%
Lower Derwent SPA	0.3%	0.3%	Not Sensitive	
Skipwith Common SAC	0.2%	0.2%	0.6%	0.6%
Skipwith Common SSSI	0.2%	0.2%	0.6%	0.6%
Humber Estuary SAC	0.2%	0.2%	Not Sensitive	
Humber Estuary SPA/SSSI	0.2%	0.2%		
Brighton Meadows SSSI	0.3%	0.3%	2.0%	2.1%
Eskamhorn Meadows SSSI	0.1%	0.2%	0.2%	0.2%

Receptor	Annual Mean N-Dep (Max Impact as % of CL)		Annual Mean Acid Dep (Max Impact as % of CL)	
	2022 ES	Feb 2023 Update	2022 ES	Feb 2023 Update
Derwent Ings SSSI	0.2%	0.2%	1.6%	1.6%
Went Ings SSSI	0.1%	0.1%	0.2%	0.2%
Barn Hill Meadows SSSI	0.2%	0.2%	1.6%	1.6%
Burr Closes SSSI	0.1%	0.1%	0.4%	0.4%
Common Plantation SINC	0.1%	0.1%	Assumed not sensitive	
Disused Railway Embankment SINC	0.2%	0.2%		
Barmby-on-the-Marsh LWS	0.4%	0.4%		
Brockholes SINC	0.1%	0.1%		
Meadow East of Orchard Farm SINC	0.0%	0.0%		
Barmby Pond LWS	0.4%	0.4%		
Cobble Croft Wood SINC	0.1%	0.2%		
Hagg Green Lane SINC	0.5%	0.6%		
Sand Pitt Wood & Barffs Close Plantation SINC	0.1%	0.2%		
<b>Env. Agency Screening Criterion (as % of CL)</b>	<b>1%</b>			

## 2.13 Direct nitrosamine sensitivity analysis

The direct nitrosamine and nitramine emissions deriving from the chemical assessment of the host unit flue gas in interaction with the solvent and the process scoped out as insignificant under the H1 assessment and therefore were not required to be modelled. However, air quality and dispersion modelling were still undertaken including these direct emissions for completeness and to increase transparency.

A review of the limited trial data associated with the use of KS21™ at Technology Centre Mongstad identified a higher nitrosamine result (0.015mg/m<sup>3</sup>) than would be expected for the bespoke PCC system designed for being developed at Drax. There are several reasons that create uncertainty around the validity of this result and mean it is not representative of the Drax PCC design or a useful comparator generally. Firstly, the test was principally to understand the capture efficiency potential of the KS21™ solvent on a gas combustion plant, not specifically to understand the associated

emissions specific to the KM-CDR process. The capture plant used was not a KM-CDR process, but an alternative design. Differences include the process not having an acid wash section or demister sections in place, critical abatement techniques present on the KM-CDR process being designed for the Drax project.

In terms of sampling, the technique used to collect the sample for the nitrosamine analysis was an isokinetic impinger-based method, a method that is developed to ensure droplets are collected and form part of the analysis. Thus, without the use of a demister in combination with both water and acid washing this would increase the risk of entrainment of droplets that would be captured by the demister solution developed for the Drax specific KM-CDR process.

Notwithstanding the conclusion, sensitivity analysis was still undertaken in relation to this result, to fully understand the potential impact to human health under the precautionary principle.

This analysis included a revisiting of the Environment Agency's H1 assessment, which showed an emission equivalent to the nitrosamine result of the single test point from Technology Centre Mongstad analysis would be scope in requiring further assessment.

Additional sensitivity modelling was undertaken on the basis that it scoped in. This found that due to ~98% of the modelled nitrosamine within the modelling originating from the photochemical reaction-degradation of the primary and secondary amines in the atmosphere, the uplift in the direct emissions associated with the single test result has no discernible impact on the overall results relative to the original modelling undertaken.

### **3.0 Additional Best Available Techniques for the emissions to air from PCC**

As part of the first submission the best available technique for amine control was identified as (i) up to three water wash levels with associated mix of demister technology (ii) an additional acid wash section with a demister section. Subsequent discussions with the Environment Agency have resulted in the inclusion of additional information to support and evidence the criticality of the demisters in controlling the transition of small droplet and vapour to a potential release.

#### **3.1 Aerosol and Droplet control**

The KM-CDR process has been designed to minimise these releases through a multi-level wash which will be designed to include up to four demister systems and three levels of structured packing. The demister solution is being developed by MHI based on the emission data provided by Drax in combination with process chemical engineering and modelling. The final design will be based on a combination of proprietary and non-proprietary demisters developed to abate droplet and vapours within the flue gas stream.

The demister solution is being specifically developed to optimise the removal and recovery of ultra-fine sub-1-micron droplets and vapours post the wash sections. Allowing these to be re-entrained within the associated wash sections and where for the water wash sections the amine solvent is recovered back to the absorber/ regenerator process and other substances such as degradation compounds can be removed.

For those droplets and vapours greater than 1-micron the demister systems are extremely effective at removal and recovery via the wash sections to the main capture process.

## 4.0 Carbon Dioxide High Pressure Compression and Venting

The final design of the high-pressure venting is highly dependent on the requirements of the carbon dioxide transport system currently in development. As with several elements of the project, the government driven timeline for the development of the CCS clusters has several interdependent processes and projects working in parallel.

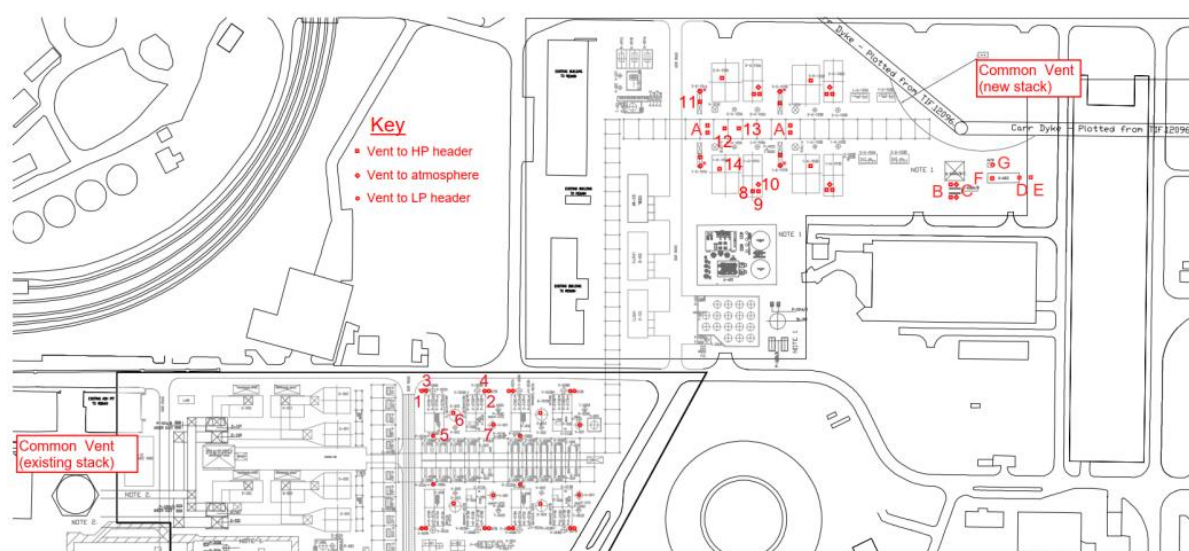
This is particularly true of capture activities and transportation and storage activities. The size and requirements of the transport system are driven by the location and size of the capture facilities they are intended to serve. Furthermore, the compression and CO<sub>2</sub> quality requirements are driven by the requirements of the transport system, a distinctive circular issue requiring a partnership approach to conclude.

Presently, an envelope of operating parameters has been provided to capture projects by the transport operator, with the transport line supporting the Drax Site identified as being a dense phase transport system with CO<sub>2</sub> pressures required of between 90 and 135 barG. The dispatchable tonnages for the PCC process to dispatch to transport will be up to 540tph.

The location of the high-pressure vent has been selected based on the layout and operation requirements of the site, with a provisional height of 20 metres being used for the CO<sub>2</sub> venting study done under pre-FEED. The location of the CO<sub>2</sub> vents and associated release points are shown in **Figure 2**. All but two vents (from the CO<sub>2</sub> analysers) vent either to the LP header and out the main stack, or to the HP header and via the new HP common vent.

Dispersion modelling has been undertaken for the new HP common vent at our flow rates of 100%, 25% 10% and 5% of maximum compressor capacity across a range of CO<sub>2</sub> concentration and atmospheric conditions. These atmospheric conditions were summer, with a warm buoyant atmosphere (Pasquill Category 5/D) to winter cold conditions with a cold stable atmosphere with low wind conditions (Pasquill Categories 1.5/f, 1.5G, 1G). The resulting contours are shown in **Figure 3**

**Figure 2 – CO<sub>2</sub> vents and destinations**

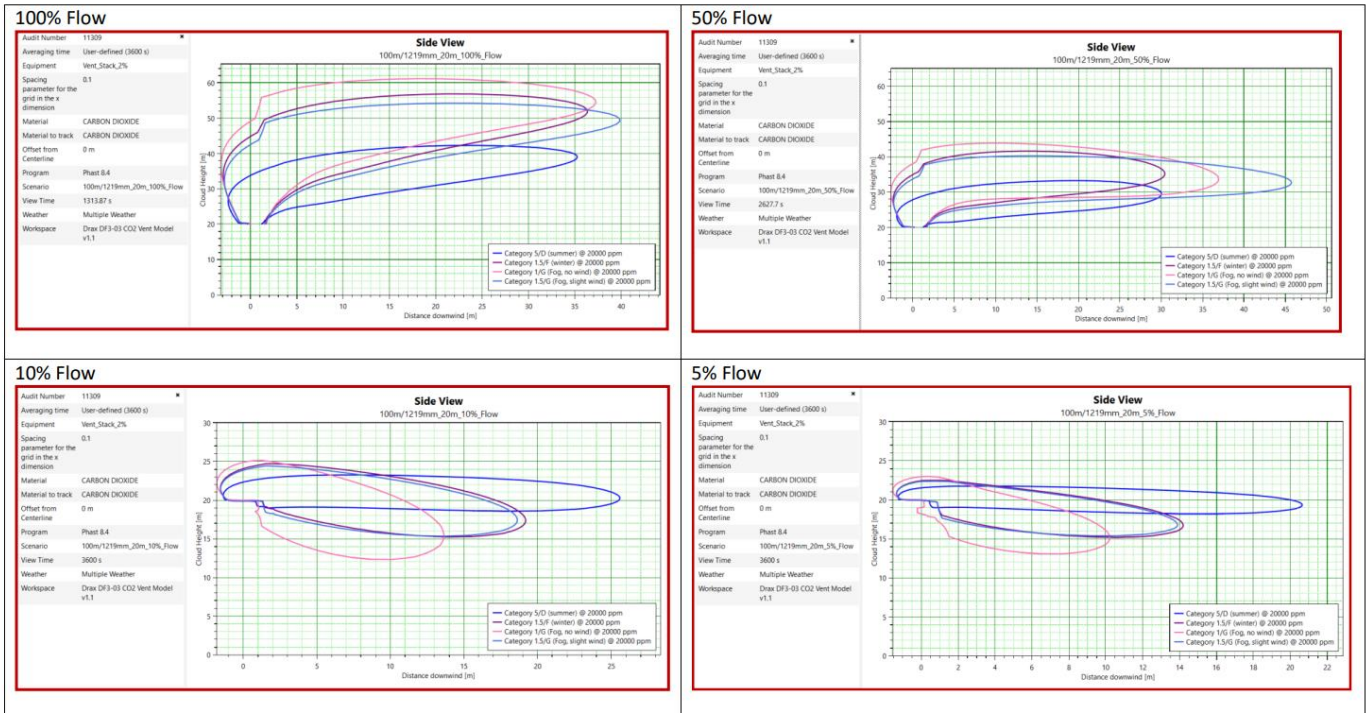


The result of the modelling were that CO<sub>2</sub> concentration above 2% did not indicate any cloud 'slumping' effect across any of the modelled conditions. At 2% some 'slumping' occurred at lower flowrates, below 10% of normal venting flowrate, in low wind stable winter conditions. however, these did not reach ground level, with the cloud remaining above 10 metres. For 0.5% concentration CO<sub>2</sub>

the cloud would reach ground level across all flowrates but only in the low wind, stable winter conditions. Such low flow rates would be of very low likelihood and short duration remaining within the site boundaries with normal venting operations operating between 50% and 100% flow rates. So, the any risk beyond the site boundary is extremely low.

**Figure 3 – CO<sub>2</sub> vents and destinations**

**C.1 2% CO<sub>2</sub> Contour (4x the 8-hour TWA; 1.33x the 15-min STEL)**



**4.1.1 Transport and Storage Interface Challenges**

The operational parameters of the transport system operator (in term of ability to vary the site export parameters in term of tph etc) are still not decided and critical to the design and operation of the high-pressure compression system. Until some of these more detailed elements are more fully understood the final compression design cannot be fully developed or will have to be finalised with the level of information available at the point a final decision is required to achieve the project timeline and developed further thereafter.

**5.0 PCC Operation and Control**

The operation and control of the PCC units is critical to the maintenance of the solvent and by association, the emissions from the absorber. This was a key element in the selection of MHI as our technology supplier and key partner in the provision of PCC technology. The KM-CDR system has more maturity and increased development than any other PCC system available. This, coupled with the selected proprietary solvent gives Drax reassurance in the operation and control aspects of the technology. The key elements that are critical to monitoring and controlling related to the environmental aspects of the PCC technology are outlined within this section.

**5.1 Start up and Shut Down Parameters**

**5.1.1 Emission to Air**

The operation and start-up and shutdown of the PCC are closely linked to, and balanced with, the operation of the host unit. To achieve a stable operating position several criteria, need to be achieved within the absorber and associated systems. The proposed start up and shutdown criteria is based on the principal activities that define the PCC to be stable and operational. **Table 18** identifies the criteria proposed for the start-up and shutdown point for emission monitoring for releases to air to commence.

Whilst these criteria are appropriate to monitor releases to air during start-up and shutdown, not suitable for monitoring the CO<sub>2</sub> capture rate due to several additional systems and processes that need to stabilise to enable, capture to be optimised. Additional criteria are proposed in **Table 19 of section 6.1.12**.

The criteria have been chosen to ensure that emission monitoring is undertaken at the earliest stable opportunity to meet the proposed permit limits. It should be noted that these are based on the best available information prior to build and commissioning, and they may need to be refined post commissioning once better operational data is available.

**Table 18 - Emission Monitoring Start-up and Shut-down Criteria**

***Start-up Criteria for Emission monitoring***

<i>Proposed Criteria</i>	By-pass Damper Closed	Flue Gas Blower In service	CO <sub>2</sub> capture unit >50% load
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***Shutdown Criteria for Emission monitoring***

<i>Proposed Criteria</i>	CO <sub>2</sub> capture unit <50% load	By-pass Damper open >50%	
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### 5.1.2 Start-up and Shutdown CO<sub>2</sub> Efficiency (capture rate)

The criteria that define when the PCC system is in a stable operational position to allow suitable monitoring of emissions to air to begin and that where CO<sub>2</sub> capture rate monitoring should start are different to ensure the most effective monitoring and protections are in place. Drax notes that the capture rate methodologies will also be developed to underpin subsidy business models.

From a CO<sub>2</sub> capture position there are additional steps that need to be achieved to ensure the capture rate is reflective of stable normal operations. These criteria are outlined for agreement in **Table 12**. The selection of these criteria is to ensure that the PCC system is operating in a stable position producing a suitable quality of CO<sub>2</sub> for compression and transportation as soon as all start-up criteria are met. Drax have selected this position on the best information available.

**Table 19 – Capture Rate Monitoring Start-up and Shutdown Criteria**

***Start-up Criteria for Capture Rate monitoring***

<i>Proposed Criteria</i>	Low Pressure CO <sub>2</sub> vent normal operation mode	CO <sub>2</sub> dehydration unit in service
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***Shutdown Criteria Emission Monitoring***

<i>Proposed Criteria</i>	CO <sub>2</sub> dehydration unit out of service	
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## 5.2 Other than Normal Operational Conditions

There are difficulties in identifying all the potential Other than Normal Operational Conditions (“OTNOC”) that could be develop from operating a PCC connected to a cluster transport and storage system and dependant on a host unit connected to the GB electricity network. Drax has reviewed the operational aspects of the PCC to identify potential OTNOC positions

### **5.2.1 Flexible response to Transport Requirement**

There are several potential operational scenarios where the availability of dispatch tonnage to the transport system may be restricted for technical reasons. Depending on the situation the PCC may be required or chosen to operate outside its normal operational envelope, depending on the duration and nature of the restriction, to avoid the need to shut down and restart for short or limited duration restrictions.

Although capture positions outside the normal envelope are potentially technically feasible, they would sit outside the designed normal operating constraints of the PCC process. Due to this, any operation outside of the envelope would be at a reduced performance from a capture efficiency and emissions position for the PCC and for the purposes of the permit would not be considered normal operations.

Example of events that could cause these occurrences are things like a compressor loss for the transport system operator or over capacity due to increase solvent yields. These are potential restrictions outside of our control that our PCC operations could need to adapt to during operation. It is therefore our view that these positions should be classed as other than normal operation conditions. Where these occur, monitoring will continue but given the PCC was not designed for these operational positions these should not be used for either capture efficiency or emission monitoring compliance. We are happy to work with the Environment Agency to identify a suitable reporting process to allow these periods to be captured and form part of the public record.

During these positions there is potential that the host LCP will be operating above the stable operational position and as such would be operated within the current permitted LCP limits for solid fuelled biomass plant.

The operation of a PCC activity in combination with a transportation and storage system as a combined system is a new and critical infrastructure the clarity around the operational rules around the potential interactions required for the safe and effective control of the cluster.

### **5.2.2 Malfunction and Breakdown**

The BAT guidance for PCC technology clearly lays out that a post absorber acid wash is required in terms of Best Available techniques for amine control. The PCC process as designed has four layers of water wash systems the final of which will be to contain the acidic wash media. However, this system, like other BAT required abatement technologies, could be subject to periods of mechanical or electrical defects that could result in off load periods. Drax would like to propose that the acid wash system is managed in similar ways to other abatement technologies with the application of 120 hours of malfunction and breakdown allocation.

## **5.3 Process Control and Monitoring**

Process control is important in the safe and efficient management of the PCC activity, while providing a good oversight of leading indicators critical to managing the environmental aspects of the activity. This enables proactive management of critical elements to support the environmental outcomes associated with the operation of the PCC.

### **5.3.1 Quencher Process Control Overview**

The quencher is a critical element in the control of the influent flue gas control. The operation of the absorber is linked through process control to the quencher's operational status. This process control



lock means that loss of the quencher will result in the controlled shutdown of the absorber to prevent unconditioned flue gases entering and risking the formation of the associated thermal and oxidation degradation substances.

### **5.3.1.1 Control & Monitoring**

The operation of the quench system is controlled through two key monitored parameters; each with a defined alarm and action limits. These are based on a HI/action required position and a HHI/action limit. Where a critical monitored parameter exceeds the HI limit the PCC operator will be notified on the control desk through a priority alarm. These alarms will have an action on receipt of alarm (AORA) process to follow to attempt to bring the parameter back within the normal operational envelope. Should the HHI limit be exceeded for a critical parameter then the process control system will intervene and take the quench system and the associated PCC out of service in a controlled manner.

The quencher has two critical parameters that are controlled as laid out above, these are: -

- Low water level
- Water pump failure

Each of these parameters are electronically monitored through the MHI-developed control system which has process controls that would result in the shutdown of the quencher and the absorber if any on the critical action limits are exceeded/succeeded.

### **5.3.2 Ammonia**

Drax is aware that ammonia has been identified as a potential leading indicator of solvent degradation in other projects and as such, must be monitored, managed, and subsequently controlled within the absorber. Ammonia was already identified as an emission species for PCC activities, so monitoring and compliance limits have already been proposed. However, there is very limited data to be able to substantiate a clear link between ammonia and the degradation compounds. The work to substantiate the ability of ammonia to be used as a pre-cursor to nitrosamine and nitramine formation within absorber will require significant parallel testing to be undertaken over a period time comparing the ammonia data with the nitrosamine and nitramine results of the yet to be finalised monitoring and sampling method.

#### **5.3.2.1 Monitoring Equipment**

Drax will utilise the continuous emission monitor at the reference monitoring location for the monitoring of ammonia. The analyser and location will be selected as described in section 8.1 of the first stage of our application.

#### **5.3.2.2 Control Process**

The current view that ammonia is a potential precursor to solvent degradation is based on regulator experience of operations utilising MEA solvents. However, Drax also take in to account the limited operational experience of PCC with a biomass host unit utilising the KS21™ solvent. Thus, it is proposed that a long-term period of monitoring and analysis of the ammonia emissions in comparison with the monitoring of nitrosamine and nitramine emissions are undertaken once a suitable monitoring and analysis methodology for these species is identified through the Environment Agency NPL project. Should a link be substantiated then ammonia could be used as a leading action indicator in conjunction with suitable mitigation actions to mitigate nitrosamine emissions.

### **5.3.3 Absorber Solvent Quality Monitoring**

The concentration of the active solvent is important to the operation of the absorber in relation to maximising the CO<sub>2</sub> capture efficiency and managing resources. Thus, the PCC system utilises online monitoring of the rich and lean amine to manage the concentration and quantity of active solvent to maximise capture while optimising the resource requirements of the system

#### **5.3.3.1 Monitoring Equipment**

The PCC will have a specifically scoped online monitoring system that will be used to ensure that the solvent concentration and quantity are optimised within the capture system.

The monitoring equipment will be calibrated and maintained in accordance with the original equipment manufacturer's requirements by competent persons. Any calibrations required will be at a minimum in line with the original equipment manufacturer's guidance and undertaken by trained competent persons.

#### **5.3.3.2 Control Process**

The data provided by the analysers will be utilised to adjust the levels and concentration of the solvent in line with operational parameters either automatically or manually with the governance of this forming part of the environmental management system.

### **5.3.4 Amine CO<sub>2</sub> Loading Monitoring**

The PCC system uses monitoring of the CO<sub>2</sub> loading within the rich and lean solvents systems to ensure the capture and release systems are within the required operational envelope. This is utilised in conjunction with the solvent concentration and quantification data to ensure that capture efficiency is maximised while optimising the resource utilisation of the system.

#### **5.3.4.1 Monitoring Equipment**

The PCC will have a specifically specified online monitoring system for CO<sub>2</sub> loading that will be used to ensure that the CO<sub>2</sub> is optimised within the capture system.

The monitoring equipment will be calibrated and maintained in accordance with original equipment manufacturer's requirements by competent persons. Any calibrations required will be at a minimum in line with the original equipment manufacturer's guidance and undertaken by trained competent persons.

#### **5.3.4.2 Control Process**

The data provided by the online monitoring system will be utilised to support the adjustment of the solvent in line with operational parameters, either automatically or manually, with the governance of this forming part of the environmental management system.

### **5.3.5 Flue Gas CO<sub>2</sub> Monitoring**

The levels of CO<sub>2</sub> in the absorber influent and exit gas streams are important to support the effective operation of the PCC system to ensure capture efficiency is maximised. These are the key monitors for the measurement and recording of the capture efficiency. The data these analysers provide when coupled with other data collected such as solvent CO<sub>2</sub> loading further supports the maximisation of the CO<sub>2</sub> capture by the system.

### **5.3.5.1 Locations**

The monitors for this will be located on the inlet and exit gas streams for the absorber. The locations will be selected on the basis of suitability, accounting for the requirements of BS EN14181 and 15259 taking into account that the installation is a retrofit and the as far as reasonably practicable. The precise location is currently still under development but will be confirmed as part of the detailed design work expected to start this year.

### **5.3.5.2 Monitoring Equipment**

The CO<sub>2</sub> monitoring will be undertaken by a continuous emission monitor with an appropriate MCERT QAL1 certification for the concentration range required.

The maintenance and calibration of the CEM will be incorporated within the current environmental management system already in place on managing the CEMs on the host site. This system has scored well in past operator monitoring assessments undertaken by the Environment Agency.

### **5.3.5.3 Control Process**

The monitoring output will be subject to high- and low-level alarms initially based on the original manufacturer's operational experience and guidance, which if required will be optimised by the operation of the PCC over time.

## **5.3.6 Soluble Iron Monitoring**

The PCC system monitors the loading of the iron within the rich and lean solvents systems. This is utilised as a leading indicator of the potential oxidative degradation and heat stable salts.

### **5.3.6.1 Monitoring Equipment**

The PCC will have a specifically specified online monitoring system for iron content that will be used to ensure that the concentration is within the operational envelope of the capture system.

The monitoring equipment will be calibrated and maintained in accordance with original equipment manufacturer requirements by competent persons. Any calibrations required will be at a minimum in line with the original equipment manufacturer's guidance and undertaken by trained competent persons.

### **5.3.6.2 Control Process**

The data provided by the analysers will be utilised to adjust the process using filtration and solvent regeneration to mitigate oxidative degradation and the formation and levels of heat stable salts within the solvent.

## **5.3.7 Heat Stable Solids**

The monitoring of heat stable solids, which are formed within the absorber (principally from a reaction of the low levels of SO<sub>2</sub> within the absorber and KS21<sub>TM</sub>) is undertaken. It is important to monitor these solids as a leading indicator, these directly identify when a solvent reclaiming cycle is required, and their formation directs the frequency of the reclaiming. Reducing the heat stable solid levels is a critical factor in maximising the solvents life, optimises regeneration cycles, and reducing the need for solvent makeup.

## **5.3.8 Temperature Monitoring**

It is important to the PCC system that the gas temperature across the PCC is monitored and controlled to mitigate potential thermal degradation of the solvent. This is undertaken through the monitoring and profiling of the temperatures across the PCC system. This provides operational visibility, notification to enable a level of control in mitigating critical issue related to low or high temperatures of thermal degradation of the solvent.

### **5.3.8.1 Influent Flue Gas Temperature**

As part of the temperature profiling of the flue gas across the absorber in support of operational visibility, notification and control the temperature is initially monitored at the gas/gas exit prior to entry to the quencher (direct contact cooler). The monitoring and controlling of the influent flue gas temperature enables mitigation of thermal degradation of the solvent.

#### **5.3.8.1.1 Monitoring**

Monitoring will be through an appropriate thermocouple which will feed a signal back to the control system. Maintenance and calibration will be undertaken in line with the original manufacturer's requirements by trained and competent persons.

#### **5.3.8.1.2 Notification and control process**

The signal back to the control system will have a HI notification alarm and a HHI notification alarm and process control shutdown sequence. The HI and HHI alarms will have an assigned priority and an action on receipt of alarm developed to provide the operators with a process to follow to support bring the temperature back within the normal operating range.

Thus, the influent flue gas temperature is monitored post the gas/gas heater with the control system which has a HI alarm coupled with a HHI process control system. These alarms will be accompanied by an action on receipt of alarm procedure to map the required actions that should be taken to bring the position back to within the required operational envelope for the quencher.

### **5.3.8.2 Absorber Gas Inlet Temperature**

As part of the temperature profiling across the PCC activity providing operational visibility, notification to enable control of the thermal degradation of the solvent. Temperature monitored at the absorber gas inlet.

#### **5.3.8.2.1 Monitoring**

Monitoring will be through an appropriate thermocouple which will feed a signal back to the control system. Maintenance and calibration will be undertaken in line with the original manufacturer's requirements by trained and competent persons.

#### **5.3.8.2.2 Notification and control process**

The signal back to the control system will have a HI notification alarm and a HHI notification alarm and process control shutdown sequence. The HI and HHI alarms will have an assigned priority and an action on receipt of alarm developed to provide the operators with a process to follow to support bring the temperature back within the normal operating range.

### **5.3.8.3 Absorber Gas Exit Temperature**

As part of the temperature profiling across the PCC activity providing operational visibility, notification to enable control of the thermal degradation of the solvent. Temperature monitored at the absorber gas exhaust.

#### **5.3.8.3.1 Monitoring**

Monitoring will be through an appropriate thermocouple which will feed a signal back to the control system. Maintenance and calibration will be undertaken in line with the original manufacturer's requirements by trained and competent persons.

#### **5.3.8.3.2 Notification and control process**

The signal back to the control system will have a HI notification alarm and a HHI notification alarm and process control shutdown sequence. The HI alarm will have an assigned priority and an action on receipt of alarm developed to provide the operators with a process to follow to support bring the temperature back within the normal operating range.

The temperature reaching the HHI limit for this monitoring point will activate an alarm, but this is in addition to a controlled shutdown process being implemented as part of the PCC process safety systems. This will shut the PCC activity down in a controlled way to keep the system and those operating the system safe.

### **5.3.8.4 Heat Exchangers (Solvent to Water) Temperature**

The control of the temperature associated with the solvent through the utilisation of cooling water is critical to the efficient and effective operation of the PCC system. Although the process control system looks at several critical parameters in relation to temperature monitoring it is the cooling water temperature that is critical as this provides the primary ability to cool the solvent to support the absorber efficiency.

This is monitored prior to distribution to the various heat exchangers which use cooling water to cool the solvent within the process.

#### **5.3.8.4.1 Monitoring Equipment**

Monitoring will be through an appropriate thermocouple which will feed a signal back to the control system. Maintenance and calibration will be undertaken in line with the original manufacturer's requirements by trained and competent persons.

#### **5.3.8.4.2 Notification and Control Process**

The system follows the same principal as those discussed for other parameters with a two-tier control system. This first tier is a HI critical alarm that will be instigated for the unit operator. Where this alarm is triggered the unit operator will seek to reduce the temperature in line with the associated action on receipt of alarm procedure within the management system.

### **5.3.8.5 Heat Exchangers (Solvent-to-Solvent) Temperature**

The primary purpose of the solvent-to-solvent heat exchangers is the efficient transfer of heat from the hot lean solvent to the cooler rich solvent as part of the PCC systems, thermal integration. This is monitored by various means to ensure balance between the two flows is correctly maintained. The temperature differential monitoring across both the rich and lean solvent streams will be undertaken to support optimisation of the heat transfer from the lean solvent to the rich solvent.

#### **5.3.8.5.1 Monitoring Equipment**

Monitoring will be through an appropriate thermocouple which will feed a signal back to the control system. Maintenance and calibration will be undertaken in line with the original manufacturer's requirements by trained and competent persons.

#### **5.3.8.5.2 Notification and Control Process**

The temperature across the heat exchangers will alarm back to the unit operator. The alarms will be supported by an action on receipt of alarm process that forms part of the management system for the operation of the PCC system.

### **5.3.8.6 Regenerator**

The regenerator utilises heat to release the CO<sub>2</sub> from the solvent for processing and onward transfer to the geological storage. This process requires optimising of the level of heating to maximise the CO<sub>2</sub> release for the lowest kJ of heat used. To support this, the temperature of the lean solvent is monitored to ensure that lean solvent at the bottom of the regenerator tower is within a defined envelope.

#### **5.3.8.7 Monitoring Equipment**

Monitoring will be through an appropriate thermocouple which will feed a signal back to the control system. Maintenance and calibration will be undertaken in line with the original manufacturer's requirements by trained and competent persons.

#### **5.3.8.8 Notification and Control Process**

The temperature monitoring will feed back to the unit operator and will utilise both a LO and HI alarm ethos. The alarms will have an action on receipt of alarm for each level that will form part of the management system for the system.

### **5.3.9 Post Water Wash Level Monitoring**

The water wash sections will use level indication as a substitute for a direct flow measurement. Each receiving tray that feeds the wash section will utilise high- and low-level indicators to ensure that a suitable flow level is maintained to support the wash section. In addition to the level monitoring, Drax have recognised the criticality of these sections to the environment and implemented a duty and standby pumping arrangement for both water wash sections.

### **5.3.9.1 Notification and Control Process**

The high-level and low-level alarms will be fed back to the unit operator with an alarm associated with both positions. The alarm will be accompanied with an action on receipt of alarm process which will be part of the management system for the operation.

### **5.3.10 Acid Wash pH Monitoring**

The use of an acid-based wash section is one of the few requirements that must be included in accordance with the PCC BAT guidance. The importance of the system is recognised, and monitoring is required to ensure that the acid dosing maintains an effective solution within the wash section. To do this, the system utilises duty and standby pH probes with high- and low-level alarms feeding back to the process operator.

#### **5.3.10.1 Monitoring Equipment**

Suitably ranged pH probes will be utilised to monitor the pH in the acid wash section. The probes will be maintained and calibrated in line with original manufacturer recommendations by competent and trained persons as per the current pH probes used within the host large combustion activity.

#### **5.3.10.2 Notification and Control Process**

The high-level and low-level alarms will be fed back to the unit operator with an alarm associated with both positions. The alarm will be accompanied with an action on receipt of alarm process which will be part of the management system for the operation.

### **5.3.11 Wash Level Amine Loading**

The design of the wash section is such that a sample of the solution can be collected and analysed for amine and associated substances. This will act as a leading indicator for the vapour controls in place to prevent the solvent and associated substance being carried out of the absorber.

#### **5.3.11.1 Sampling**

The sampling will be taken utilising an appropriate sampling method once the final design is known. The intention would be for this sampling method to be ISO17025 certified as part of our Site or a contracted laboratory's certification.

The sampling frequency is initially expected to be weekly but would be refined as experience and understanding of the PCC system develops.

#### **5.3.11.2 Analysis and Process Control**

The analysis of the sample will be undertaken by a ISO17025 certified laboratory using an appropriate method for the substances required to be tested. The analysis will then be reported internally to allow the operations team to make the decisions needed to refine the process if required.

## **5.4 Plate Heat Exchangers (PHE) Design Ethos**

Drax is working with MHI and various suppliers of plate heat exchangers to identify the most suitable solution available to maximise heat exchange while providing the highest suitable level of protection to the environment. This ethos resulted in the choice of a double gasket plate heat exchanger design with an embedded leak detection and spray control system.

### 5.4.1 Efficiency Considerations

The key considerations used in the selection of the PHE selection were temperature differential, target temperatures, efficiency, and plate material selection. The key parameter that we were seeking to achieve is efficient control of solvent temperatures to maximise the capture efficiency of the solvent within the system.

Based on the temperature and required efficiencies, counter flow plate design has been selected for most of the heat exchanger to be deployed due to the high heat transfer efficiency and the reduced thermal stresses endured by the PHE. In addition to the use of counter flow design material, selection is important. Generally, the two-plate material types that are expected to be utilised are titanium-based PHE to be used for solvent and cooling water and a stainless-steel design to be used for the solvent-to-solvent PHE. As well as supporting efficiency, these materials have also been chosen to mitigate the risk from thermal stress and corrosion.

The key factor in the efficiency PHE system is the cooling efficiency of the cooling system and appropriate sizing of the heat exchangers. In terms of cooling the station, and by association the PCC, the station utilises a natural draft (wet) system as defined in '*Cooling Water Options for the New Generation of Nuclear Power Stations in the UK*'. This is the most efficient option for an inland operating station where direct cooling is not applicable.

The heat exchangers design is expected to include an element of redundancy to enable maintenance and cleaning in line with supplier requirements.

### 5.4.2 Cross Contamination Control

The PHE are design to mitigate the potential risk of cross contamination. The PHE selected will utilise a dual gasket solution where the volume between the gaskets is designed to quickly move any liquid away, coupled a leak detection system to raise an alarm of the leak. This is further aided through the choice of plate and gasket materials. Titanium will be used for those PHE where solvent is being cooled directly with cooling water is to mitigate the potential failure in the plate material.

We are working with the suppliers as well as specialist providers to identify the most appropriate materials to provide gasket materials providing the most protection coupled with appropriate life span to maximise the availability and efficiency of the PCC over the operational life of the plant.

Additionally, we are working to identify the optimum plate number per sleeve to optimise heat transfer while mitigating the risk associated with the thermal and mechanical stress of the PHE.

To complement the primary controls embedded within the design of the PHE, work is underway with the suppliers to embed a suitable secondary control system such as leak detection systems, isolations and drains to mitigate the likelihood of any cross contamination occurring this will be completed within the final design element of the works.

#### 5.4.2.1 Monitoring

The heat exchangers (solvent/cooling water) under consideration utilise a dual gasket with the space between the gasket designed to expel any liquid away from the secondary gasket and out of the gap. This process enables the monitoring of PHE to identify if this occurs. These could then be combined with a process control alarm and associated action on receipt of alarm system. This system would support the PCC not only environmentally but also in protecting those working on the site.



As well as monitoring the PHE in term of gasket failures, we will also be working with our principal design team to include outlet monitoring of the PHE with the aim of identifying amine within the cooling water. This comes with a number of monitoring considerations due to the nature of the cooling water and the primary means used to detect amine (conductivity). We are assured an option will be identified which would allow any associated detection of amine to be contained through process control systems. This is within the final design package of the project. Once isolated the appropriate steps can then be taken to drain and repair the PHE identified.

### **5.4.2.2 Isolation**

It is our intention to embed a series of isolations with the PHE system to enable isolation of the PHE to suitable level to enable draining and maintenance to take place. This would enable the isolation to repair gaskets and other issues should they arise.

### **5.4.2.3 Drain Down and Decontamination**

Where a leak is identified, the PHE area in question will be isolated and a defect card raised with the required priority. The expectation at this this is that this would be classified as high priority (within 24 hours completion) work order with the work order raised and planned in line with the priority of the work.

This work would require the PHE area in question to be drained down. Draining of the cooling water and solvent systems would be done to the bunding around the PHE. This would then be tested and sent off site for treatment.

For the solvent-to-solvent systems and the solvent side of the water to solvent PHE, we are currently looking at the suitability for this to be drained down and regenerated as part through the proposed solvent regeneration systems.

The choice of PHE was also taken to minimise periods of down time due to their design enabling spare plate and gaskets to be carried on stock and swapped in and out promptly if required.

## **5.5 Solvent Selection Additional Information**

The analysis Drax has done on the MHI KS21<sup>TM</sup> solvent provides confidence that it is the best available solvent on the market today for the host units; especially when paired with the MHI KM-CDR process.

Due to the limited application of the technology on host biomass units, it is difficult to provide comparable data to support our position. Even trying to identify simple data around the MEA in PCC systems is not straight forward. Data points such as solvent usage and water demand for these systems are difficult to come by. There are a lot of reports around capture rate and capture efficiency, but the wider peripheral data is less developed

In relation to capture energy MEA has an energy demand of  $\sim 3.1 \text{ MJ/kg}_{\text{CO}_2}$  (al, 2015) whereas KS21<sup>TM</sup> only required  $2.56 \text{ MJ/kg}_{\text{CO}_2}$  for capture. Additionally, the estimated process water(non-cooling) usage is only  $0.14 \text{ m}^3/\text{t}_{\text{CO}_2}$  and the solvent usage is estimated to be  $0.27 \text{ kg/t}_{\text{CO}_2}$  based on the flue gas composition provided to MHI. This shows that the energy requirement is far lower than MEA and the system embraces resource optimisation.

## 5.6 Additional Energy and Efficiency Heat Utilisation Information

Substantial engineering resources have been deployed to develop the heat integration of the retrofitting of PCC to our existing units. The optimising of heat utilisation while minimising electrical output loss of the units is critical to the commercial operation of the site into the future. Drax believes that the integration and efficiency level that we have achieved are BAT for a retrofit of PCC on a site of our size and layout.

### 5.6.1 Electrical Output Penalty

The energy requirement of engineered carbon dioxide removal is well understood and has been a significant barrier to the deployment of these technologies. The price of carbon dioxide, couple with the criticality of the response required around climate change is making the deployment of these technologies essential to support the local, regional, and global response to climate change.

Drax have worked tirelessly to develop a heat integration system that minimises the electrical output penalty for the units with carbon capture deployed. The result of this work will enable the retrofit deployment of the technology across a limited geographical footprint with an expected operational design efficiency of 27% detailed in **Table 20**

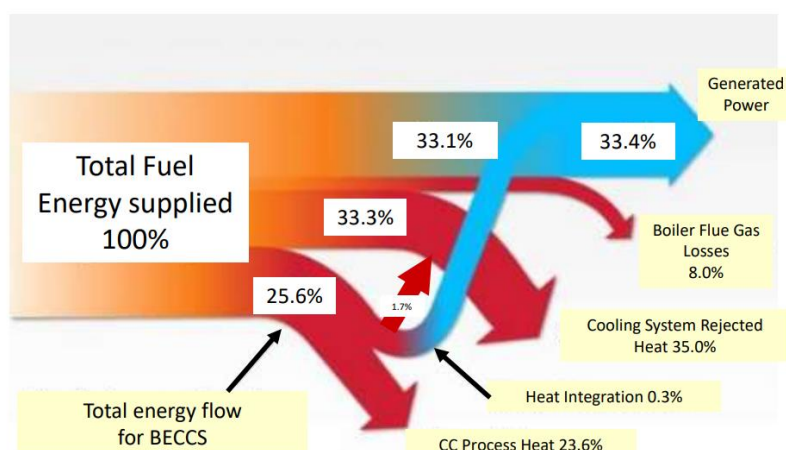
**Table 20 Breakdown of Current and Estimated Operation Performance of PCC unit**

<i>Estimated Plant Performance</i>	<b>Unit</b>	
<i>Gross Net output for LCP BREF</i>	645	MW
<i>CO2 capture per hour (full load, stable conditions, design basis)</i>	550	t/hr
<i>Electrical output penalty for heat supply and power</i>	192	MW <sub>e</sub>
<i>Gross Net output with PCC</i>	453	MW <sub>e</sub>
<i>Efficiency with PCC and Compression</i>	27.8	%

### 5.6.2 Additional Heat Utilisation Information

An extensive study around the PCC process and the best way to integrate the process from an energy and cooling perspective has been undertaken. The additional detail around this integration was included within the first submission but to further support this a Sankey diagram shown in **Figure 4** has been processed to enable the visualisation of the energy and heat integration.

**Figure 4 Energy Flow Diagram with Heat Integration Included**



## 5.7 Odour Review

An air quality assessment has been undertaken (refer to Section 7.14 of the initial Permit Variation Application) which, in addition to the usual combustion parameters, considered emissions of ammonia, aldehydes and amines. The full results, including different modelling scenarios, are included in the initial Permit Variation application, however, the predicted air quality impacts are that there will be small emissions of amines and nitrosamines and a potential decrease in emissions of all other parameters (NO<sub>x</sub>, SO<sub>2</sub>, NH<sub>3</sub>, HCl).

Odour is considered in the Environmental Risk Assessment submitted as part of this Additional Information Provision. In accordance with Environment Agency guidance 'Risk assessments for your environmental permit' on the GOV.UK website (<https://www.gov.uk/guidance/risk-assessments-for-your-environmental-permit>), the risk assessment considers the potential odour sources resulting from the environmental permit changes being applied for (i.e. the PCC process plant and associated systems), the receptors at risk from the site and the possible pathways from the sources of the risk to the receptors.

Two potential odour sources were identified: the PCC process itself and the wastewater treatment plant. The Environmental Risk Assessment concludes that the odour risk associated with the proposed changes on site is deemed acceptable (low risk) when considered in line with the intended risk management techniques. The key mitigation measures are management of the amine solvent (in both its storage and use) and robust operational control measures at the wastewater treatment plant (e.g. the use of covered tanks and enclosed equipment, where feasible).

The Drax Power Station site is currently regulated in accordance with environmental permit reference EPR/VP3530LS/V019. This permit includes the standard qualitative odour boundary condition (permit condition 3.3.1) and does not contain any specific emission limits or monitoring requirements in relation to odour. Additionally, the site does not have a history of odour complaints and the Environment Agency has never requested Drax to produce and submit an Odour Management Plan (OMP) for the site under the requirements of permit condition 3.3.2. Therefore, in combination with the fact that the proposed changes being applied for are not anticipated to have a significant impact beyond the installation boundary, i.e. at sensitive receptors, it is not considered necessary to submit an OMP as part of the Permit Variation Application.

## 5.8 Noise Mitigation measures

As detailed in Section 12 of the Permit Variation Application (Stage 1 submission), a noise assessment of the proposed project has been undertaken in line with BS4142:2014+A1:2019. The assessment predicted the likely noise impacts at a number of pre-selected sensitive receptors within a 2 km study area surrounding the site. The conclusions reported in the Variation Application are that during both the daytime and night-time operational periods, the ambient noise levels would be dominated by the existing sound climate and, therefore, no change in ambient noise levels is expected due to the operation of the PCC plant at any sensitive receptor.

The proposed activities considered in the noise assessment are the carbon capture technology followed by carbon dioxide processing and compression before being transported off site via pipeline. For a full description of the proposed activities refer to Section 2 of the Permit Variation Application (Stage 1 submission). A site plan showing the location of the proposed activities is provided in Appendix C.

The noise assessment included noise source data for the new plant and equipment required for the PCC process, including the compressor buildings (2 compressors per building and each compressor comprising the following components: compressor casing, main motor casing, LO console, intercoolers 1-5 and recycle cooler), pumps (96 pumps in total comprising 3 different pump types), combined power turbine buildings (2 steam turbines per building) and four gas booster fans.

Noise has also been considered in the Environmental Risk Assessment submitted as part of this Additional Information Provision. In accordance with Environment Agency guidance 'Risk assessments for your environmental permit' on the GOV.UK website (<https://www.gov.uk/guidance/risk-assessments-for-your-environmental-permit>), the risk assessment considers the potential noise sources resulting from the environmental permit changes being applied for (i.e. the PCC process plant and associated systems), the receptors at risk from the site and the possible pathways from the sources of the risk to the receptors. The Environmental Risk Assessment concludes that the noise risk associated with the proposed changes on site is deemed acceptable (low risk) when considered in line with the intended risk management techniques.

The Drax Power Station site is currently regulated in accordance with environmental permit reference EPR/VP3530LS/V019. This permit includes the standard qualitative noise boundary condition (permit condition 3.4.1) and does not contain any specific emission limits or monitoring requirements in relation to noise. Additionally, the site does not have a history of noise complaints and the Environment Agency has never requested Drax to produce and submit a Noise Management Plan (NMP) for the site under the requirements of permit condition 3.4.2. Therefore, in combination with the fact that the proposed changes being applied for are not anticipated to have a significant impact beyond the installation boundary, i.e. at sensitive receptors, it is not considered necessary to submit a NMP as part of the Permit Variation Application. This is further justified because the Permit Variation Application only considers the changes being proposed on site (i.e. the PCC process plant and associated systems) and, therefore, it would not make sense to develop a NMP for these aspects in isolation. If a NMP is considered necessary, it is considered that one should be developed for the installation as a whole, which would form part of normal permit condition regulatory controls, rather than forming part of the Permit Variation Application determination process. This approach has been agreed with the Environment Agency's National Permitting Team during other substantial variation applications.

The PCC process is still subject to detailed design, which will ensure that BAT for noise is demonstrated, however, certain noise mitigation measures have already been committed to as detailed in the Environmental Risk Assessment. Furthermore, BAT I (XV) in the LCP BREF confirms that the requirement for a Noise Management Plan is only applicable where a noise nuisance at sensitive receptors is expected and/or sustained which is not the case for this variation application.

## 5.9 Water Treatment Plant Overview

The design and operation of the quencher/ direct contact cooler and treatment plant are principally equivalent to the current water treatment activity associated with treatment of flue gas desulphurisation wastewater. This is on the basis that the quencher is specifically designed to remove sulphur oxides from the influent flue gas stream and the resulting wastewaters would contain the substances with some variation in concentrations to the input stream over the current plant. To this regard it is our opinion that the current activity 5.4 Part A (1)(a)(ii): disposal of non-hazardous waste with a capacity exceeding 50 per day – physico-chemical treatment remains valid for this activity under permitting. Therefore, although the treatment plant comprises a schedule 1 activity, we are not applying to add a new schedule 1 activity to the permit as it is already covered.

On this basis it is also our view that the most appropriate BAT-AEL for plant discharge remains that of the large combustion Plant BAT conclusions for FGD wastewater treatment BAT 5 and BAT 15 (Union, 2017) as shown in **Table 21**. Thus, the plant will be designed to meet the BAT-AELs as shown in **Table 21** prior to the resulting water stream being discharged back to the cooling recirculation system for further utilisation. The utilisation of the LCP FGD wastewater treatment BAT provide a far more stringent limits than that for the waste water treatment BREFs as shown in **Table 22**

**Table 21 LCP Best Available Techniques FGD discharge limits.**

<i>Substance/Parameter</i>	<b>Monitoring Frequency</b>	<b>BAT-AELs Daily average</b>	<b>Units</b>
<i>Total Organic Carbon (TOC)</i>	Once per calendar month	50	mg/l
<i>Chemical Oxygen demand (COD)</i>		150	mg/l
<i>Total Suspended Solids (TSS)</i>		30	mg/l
<i>Fluoride</i>		25	mg/l
<i>Sulphate</i>		2.0	g/l
<i>Sulphide</i>		0.2	mg/l
<i>Sulphite</i>		20	mg/l
<i>Arsenic</i>		50	µg/l
<i>Cadmium</i>		5	µg/l
<i>Chromium</i>		50	µg/l
<i>Copper</i>		50	µg/l
<i>Nickel</i>		50	µg/l
<i>Lead</i>		20	µg/l
<i>Zinc</i>		200	µg/l
<i>Mercury</i>		3	µg/l

The system will have the ability to move the wastewater stream to the onsite purge system which is then pumped and discharges to river via the current W1 discharge point. This system has continuous monitoring for temperature and pH in place with embedded process control to shut pumps down where the monitoring exceeds the defined limit values either low or high.

**Table 22 Comparison of BAT-AELs for Emissions to Water from LCP and Waste Treatment BREFS**

<i>Parameter</i>	<b>LCP BREF BAT-AEL*</b>	<b>Waste BREF BAT-AEL**</b>	
		<b>All waste treatments</b>	<b>Water-based liquid waste</b>
<i>TOC</i>	50 mg/l	60 mg/l	100 mg/l
<i>COD</i>	150 mg/l	180 mg/l	300 mg/l
<i>TSS</i>	30 mg/l	60 mg/l	
<i>Fluoride</i>	25 mg/l	N/A	
<i>Sulphate</i>	2 g/l	N/A	
<i>Sulphide</i>	0.2 mg/l	N/A	
<i>Sulphite</i>	20 mg/l	N/A	
<i>Arsenic</i>	50 µg/l	N/A	100 µg/l
<i>Cadmium</i>	5 µg/l	N/A	100 µg/l

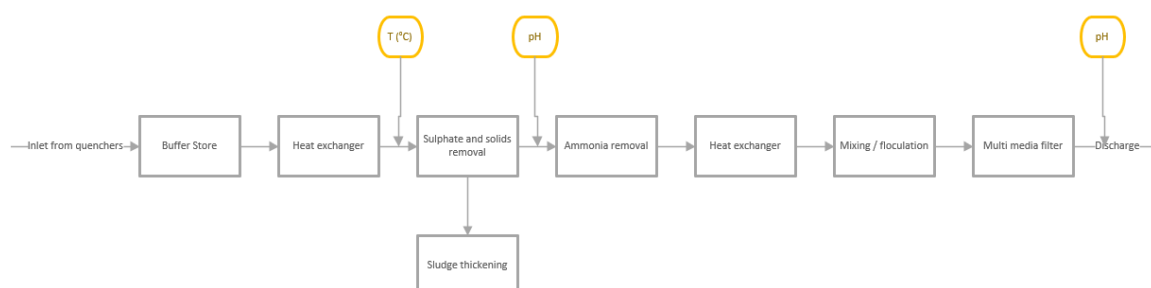
<i>Chromium</i>	50 µg/l	N/A	300 µg/l
<i>Copper</i>	50 µg/l	N/A	500 µg/l
<i>Nickel</i>	50 µg/l	N/A	1000 µg/l
<i>Lead</i>	20 µg/l	N/A	300 µg/l
<i>Zinc</i>	200 µg/l	N/A	2000 µg/l
<i>Mercury</i>	3 µg/l	N/A	10 µg/l

An H1 risk assessment for emissions to water was provided in the Permit Variation Application (Stage 1 submission). Emissions from the wastewater treatment plant are also considered in the Environmental Risk Assessment submitted as part of this Additional Information Provision (Stage 2 submission). With regards to receptors, we are not aware of any newly designated habitats sites since the previous water emissions risk assessment was carried out.

### 5.9.1 Design

The design of the final water treatment plant is still not finalised but the notional design on which the final design will be developed from is shown in **Figure 5**.

**Figure 5 – block flow of notional design for wastewater treatment facility**



The assumed first step in the process is the treatment of the sulphites, sulphate and total suspended solids which are expected to be managed through precipitation utilising a lime addition. Solids would then be removed by clarification or similar ahead of air stripping this could be aided using chemicals such as ferric chloride etc.

Next the plant is expected to undertake ammonia removal utilising a further raising of the pH through chemical addition to maximise the free ammonia prior to air scrubbing. Any heat requirement would be provided from the quencher condensate directly. The stripped air would then be treated using air scrubbing with acid addition (potentially sulphuric) to form a salt such as ammonium sulphate and eliminate any ammonia emissions to air from the process.

Finally, the treatment plant will utilise flocculation using a TMT15 or similar product to assist with metal removal, specifically mercury and cadmium. This will then be followed by a multimedia filtration system to ensure the BAT-AELs for flue gas desulphurisation plant are achieved.

The system will have online monitoring for temperature and pH and additional sampling points for the periodic sampling of the wastewater, post treatment. The maintenance of these will be in line with

the original equipment manufacturers requirements and managed by an electronic preventative maintenance system. These devices will also have associated alarms and action on receipt of alarm system associated once the final design has been concluded.

The overall plant will also provide appropriate unloading facilities for tankers and other vehicles required to support the plant operation.

The sludge disposal and handling will be determined using WM3 guidance once the final design has been determined.

## 5.10 Raw Material Needs and Management

The expected PCC raw materials needs are identified in **Table 23**. This is based on current design expectations and may alter as the final design is progressed in relation to the water treatment plant and some other peripheral activities. However, those associated directly with the PCC are less likely to be subject to further refinement to any material degree.

**Table 23 Raw material and usage list normal operation**

<i>Raw Material</i>	<b>Units</b>	<b>Resource Requirement per unit</b>	<b>Estimated Annual Resource Requirement and Units</b>	
<i>Cooling water</i>	m <sup>3</sup> /hr	115691	912,732,575	m <sup>3</sup>
<i>Towns Water</i>	m <sup>3</sup> /hr	26.2	206,702	m <sup>3</sup>
<i>Process water</i>	m <sup>3</sup> /hr	63.5	500,976	m <sup>3</sup>
<i>Demineralized water</i>	m <sup>3</sup> /hr	56.4	444,962	m <sup>3</sup>
<i>KS21<sup>TM</sup></i>	kg/t-CO <sub>2</sub>	0.27	2,160	t
<i>Caustic Soda</i>	kg/hr	640	5,049	t
<i>Sulphuric Acid</i>	kg/hr	20	158	t
<i>Precoat Agent</i>	kg/cycle	1330	NA	
<i>Anti-foam Agent</i>	kg/hr	1.11	9	t

## 5.11 Emissions Monitoring During Commissioning

The current position on the monitoring during the commissioning period is still to be determined as several critical elements are yet to be finalised either by design or by parties external to the project.

Critically, the continuous emission monitoring equipment for the system has not been finalised nor the sampling location and platform requirements for the PCC process. The development of the nitramine and nitrosamine sampling and analysis methods have not been completed. There is also work ongoing with internal and external partners on identifying suitable analysis methods around the speciation of the primary and secondary amines.

Additionally, the detailed information and timeline associated with the transport system will be required to finalise the commissioning schedule to support the PCC activity.

Once these critical elements have developed in detail, then a commissioning plan will be developed in terms of monitoring with expectation that continuous emission monitoring will be in place and in use both pre and post the PCC activity to ensure the host LCP remains compliant and to enable cross comparison with the calibrated and uncalibrated monitoring equipment. Expectation is some periodic testing will be done but this will be dependent on the sampling methods and durations, once these are better understood.

Post commissioning all continuous emission monitoring will be QAL2 in accordance with the standards and a period of periodic testing for nitramine, nitrosamine, primary and secondary amines will be undertaken

## **5.12 Unplanned Emission to the Environment**

The existing site is a lower tier COMAH site, which coupled with the current permit requirements ensure that the management systems are robust in the prevention and management of unplanned emissions. The current system is underpinned by all none land drainage discharges requiring to be pumped off site. A position supported by process control systems and monitoring on the main purge (discharge) pumps for the current critical parameters in pH and temperature.

The PCC system is also being developed, as noted in the first variation application submission, with specific bunding and drainage zones to support each of the key substances used by the facility. Each zone will have a specific disposal route tailored to the substances. The route out from each of these zones will be based on testing of any liquids before a defined outlet route is selected.

In addition to this zone-specific drainage, the system will also accommodate a leak detection system for key components. This supported by a fully welded distribution system for the amine solvent. The finalised detection system will not be fully formed till detailed design but will be risk based to ensure effective management of the chemicals utilised within the PCC.



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