Interested Party Number: 20032286

Drax Bioenergy with Carbon Capture and Storage, PINS Reference: EN01012

Comments on responses to the Examining Authority's written questions and Comments on any other responses received by Deadline 2.

As the NSIP process progresses, further questions and comments arise. These are in part in response to additional information and responses at each deadline, and in part to additional reading provided by the applicant such as the BAT guidance.

1. Particulates – there is no provision in the design for Electrostatic Precipitation Scrubbing (EPS) to remove fly ash and other particulates, yet the BAT guidance clearly states that this is a potential issue. Section 3.3.1 of the BAT guidance says:

Aerosols

*Sulphur trioxide (SO3) droplets **and fine particulates*** should not be present in the flue gas. If they arise in the PCC process they can cause significant amine emissions.*

The level of emissions (mainly solvent amines) are not directly related to aerosol measurements. Monitoring aerosols is difficult and aerosol quantities may also vary significantly over time.

Aerosols might be present, for example, because of significant SOx in the flue gas. Where this is the case, you should carry out long-term testing on a pilot plant or the actual plant, with all planned countermeasures in place, to show satisfactory operation. You should also carry out regular isokinetic sampling in the operational plant to assess total vapour and droplet emission levels.

Other flue gas impurities

You may need to remove materials in the flue gas that would accumulate as impurities in the solvent (such as metals, chlorine and fly ash) to lower concentrations than is required under the LCP BREF. ** This is to ensure satisfactory PCC plant operation. Whether you need to do this will depend on the specific solvent properties and the effectiveness of the solvent management equipment (such as filtering and reclaiming).*

You should assess the effects of flue gas impurities through realistic, long term pilot testing. In general, your PCC plant must abate these types of flue gas impurities

before the residual flue gases are finally released to atmosphere.
* My emphasis

Because of the claimed commercial confidentiality surrounding the proprietary solvent, we cannot know if there is a risk of fly ash and other materials building up in the solvent, and seek an explanation of this aspect of the proposed operation. It is reasonable to assume that there will be fly ash present in the flue gas stream, and we question why there appears to be no EPS designed in.
We know that the applicant received wood pellets from a number of sources, and that the supply includes both hard and soft woods – presumably with different chemical composition that can influence chemical contamination of the flue gases as well as the amount of fly ash.

2. Amines

We have a number of questions about the operational use of amine solvents:

Transport – how will the initial bulk import of solvent to the solvent store and to charge the CCS system be achieved? Is there a risk assessment for this?
How will the operational import of new solvent to replace losses be achieved? How frequently will this be required? Is there a risk assessment for this, particularly the initial bulk import?

Emissions Monitoring – what plans are in place for emissions monitoring of the solvent and any degradation products? Is this part of the planning consent as well as the environmental permitting?

The BAT guidance on this is clear in section 3.4.2 (Page 9):

3.4.2 Point source emissions to air

You must include monitoring to demonstrate compliance with the IED Chapter III ELVs and the LCP BREF BAT AELs at normalised conditions.

You must also monitor for:

- *ammonia*
- *volatile components of the capture solvent*
- *likely degradation products such as nitrosamines and nitramines*

Your monitoring may be by either:

- *continuous emissions monitoring ('on line')*
- *periodic extractive sampling ('off line') – where aerosol formation is expected, this must be isokinetic*

Emission sampling point must also comply with M1 sampling requirements for stack emission monitoring.

Because this guidance is so explicit, we believe that monitoring arrangements should be part of the planning consent as well as the licencing permit.

3. Carbon dioxide

Section 3.4.4 of the BAT guidance, on monitoring of CO_2, is clear that the total capture level needs to be monitored as well as releases and the quality of the gas stream to the pipeline for long term storage.

3.4.4 Monitoring of CO2

To meet the required specification, include:

- *CO2 mass balance*
- *CO2 in fuel combusted*
- *total capture level (as a percentage)*
- *CO2 released to the environment*
- *CO2 quality*

We have questions about the capture rate.
During Issue Specific Hearing 1, and in their response to it, the Applicant made confident claims of an *average* capture rate of 95%. We seek clarity on this. In everyday language, "average" and "mean" are synonymous. We would like explicit confirmation that this "average 95% capture rate" does indeed require the mean capture rate to be 95%, not the median or mode, which are sometimes also referred to as averages. This is important for operational monitoring and public confidence.

In our responses at Submission Deadline 2, we questioned the applicant's confidence in achieving the 95% capture rate and the lack of evidence for this. We ask the ExA to push the applicant to provide evidence for this confidence, bearing in mind that the academic literature on existing CCS plants, including point source/power station Post Combustion Capture (PCC) indicates that a 60-70% capture rate over time would be ambitious.

In response to our questions on this, the applicant (in document 8.10.1 Applicant's Responses to Issues Raised at Deadline 1) repeated the assertion that the process is designed to capture 95% of the CO_2 in the flue gas stream, but provided no further evidence to cover the gap between the design assumptions and historic operation of PCC in power stations. We have read and understood the BAT documentation, as quoted in this document, and still believe that there is a gap between design and operation. This gap will be pursued at the Environment Agency consultation because it is clear that where the reality gap is predictable, it must be considered.

Operational considerations

During ISH1, the applicant appeared to make contradictory statements, implying at one point that the two abated (retrofitted) units would be running continuously. At another point, the applicant suggested that the two abated units, like the two unabated units were likely to be deployed flexibly to meet demand due to the intermittency of supply to the grid from renewable generation (from wind and solar). This second model is clearly the expectation from section 3.6 of the BAT guidance.

3.6 Capture level, including during flexible operation

Capturing at least 95% of the CO2 in the flue gas is considered BAT. You can base this on average performance over an extended period (for example, a year). To achieve this, you should make sure the design capture level for flue gas passing through the absorber equates to at least 95% of the CO2 in the total flue gas from the power plant. If you process less than the full flue gas flow, your capture rate will have to be correspondingly higher. Over the averaging period, your capture level may vary up or down.

As the fraction of intermittent renewable generation in the UK rises, CCS power plants will need to start and stop more often, and possibly also operate at variable loads. It is therefore important that CO2 can also be captured at high levels during these periods, including during start-up and shutdown, to maintain high average capture levels.

A method to maintain capture at normal rates or higher at all times using solvent storage has been identified in the BAT review. This, or alternatives that can achieve equivalent results, is considered BAT. If your PCC plant is not initially constructed with this capability, your permit application should show how you may retrofit it.

Therefore we would like clarification about whether the applicant is planning for one or both operational models, and whether they have confidence in meeting the 95% average capture rate in both scenarios.

Section 3.6 of the BAT guidance is clear that capture rates need to average 95% during start-up and shutdown. The guidance says that the use of solvent storage has been identified in the BAT review as a method of improving capture rates, and that if the PCC plant is NOT designed with this facility, it must be possible to retrofit it. It is not clear to the lay person whether the current application includes this, either in the current DCO or as a potential further addition requiring planning permission. Clarity on this would be appreciated as well as whether the BAT suggested solvent storage process is designed in.

4. BAT Review

The Bat guidance directs readers to the BAT Review site [redacted]) which references specific documents to further inform the BAT Guidance, including
Gibbins, J., Lucquiaud, M. (2022) *BAT Review for New-Build and Retrofit Post-Combustion Carbon Dioxide Capture Using Amine-Based Technologies for Power and CHP Plants Fuelled by Gas and Biomass and for Post-Combustion Capture Using Amine-Based and Hot Potassium Carbonate Technologies on EfW Plants as Emerging Technologies under the IED for the UK*, Ver.2.0, December 2022. This document is available from [redacted]

From p29-30 of this document:
There are many amines, with an infinite scope for variety in the range of amine-containing blends initially fed into the plant. Further complexity is introduced as

amine inventories degrade and accumulate possible additives and impurities as they approach long-term equilibrium compositions, with the additional modifying effects of reclaiming and other solvent maintenance during commercial service. Reclaiming and solvent management are often omitted from pilot tests undertaken for solvent development or comparison, but are obviously absolutely essential if pilot tests results are to represent those on an actual commercial plant, where some form of reclaiming and other solvent management techniques can be expected to be deployed.
*It cannot be too strongly emphasised that it is this long-term, equilibrium composition and solvent behaviour that will determine the solvent-related environmental performance of the plant, not the behaviour observed in tests starting with relatively fresh solvent and with little or no reclaiming or other solvent maintenance to remove impurities, as would be required in commercial operation.** *It is self-evident that the average long-term concentration of any given impurity in the solvent will be the value at which, for that specific impurity, average removal rate matches average formation rate (for degradation products) or average addition rate (for flue gas impurities or corrosion products). Thus, tests that do not include the use of the impurity removal procedures that will be used in full-scale applications can never match the solvent composition (and therefore behaviour) that will be observed in practical commercial applications.*
* Authors' emphasis

On page 31, the authors quote a 2018 review of the Boundary Dam CCS plant after 4 years of operation which emphasises their point:
'The capture facility at Boundary Dam has been operating since 2014, almost four years. During this time, there have been difficulties with the plant being able to supply the contracted CO2 to its off-taker. There were a significant number of design deficiencies and construction quality issues to manage. In addition, the Capture Plant continues to experience significant issues with the amine absorbent chemical that is fundamental to the process.
These issues were, and continue to be, tackled in order of priority: 1) safety, 2) reliability, and 3) efficiency and cost-effective operation. As SaskPower implemented projects to correct the issues of which it was aware, the process was further complicated by the emergence of previously undetected issues that required further corrective action. At times, this involved long lead times to procure and install specialized equipment. This, coupled with amine-related issues, has contributed to lengthy outages and underperformance of the plant.

The commercial confidentiality surrounding the applicant's proprietary solvent, and the associated lack of (publicly available) data from trials provides little confidence that the actual operation of the retrofitted PCC will over time meet the required 95% capture rate. The reasons to doubt the applicant's confidence are abundantly clear, so we must ask that the evidence for the applicant's confidence be clear and unambiguous and that their pilot project(s) anticipated the above reported issues.

Solvent Safety
In section 2.3.4 of the Gibbins and Lucquiaud review, the authors rate and rank potential solvents and solvent mixes in terms of safety, effectiveness and other variables. See **for example** Table 2.1 from page 28 (see Appendix A). We cannot

assess the solvent in terms of its effectiveness, or its likelihood to degrade and interact with contaminants such as (so-called) NO_x, because we are prevented from knowing the exact make-up of the proprietary solvent.

Again, we have to ask that **at the very least**, the applicant explains this in detail in a closed session with the Examining Authority and later, with the Environment Agency. This commercial confidentiality cannot extend to the statutory bodies charged with consenting, permitting and licencing the BECCS operations.

5. Flood Risk Assessment

We are pleased to see that the applicant has further consulted with the Environment Agency over the risk of tidal and storm surge flooding. We hope that the mitigation measures planned are adequate for the operating and decommissioning life of the site, given the frequently changing evidence of accelerating sea level rise and associated storm surges.

6. APPLICANT'S RESPONSES TO EXAMINING AUTHORITY'S FIRST WRITTEN QUESTIONS

Drax Bioenergy with Carbon Capture and Storage Infrastructure Planning (Examination Procedure) Rules 2010, Rule 8(1)(b); Planning Act 2008; Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009
Document Reference Number: 8.9

We note that there are a number of unanswered questions within this document. Although we acknowledge that the document is entitled "Applicant's responses…" it is clear that other agencies have been asked questions and have answered them. As a point of clarification of process and procedure, when will all questions in this document be answered, for example by Natural England, UKHSCA and NYCC?

7. Applicant's responses to issues raised at deadline 1. Document 8.10.1

We welcome the applicant's responses to the points we raised. We recognise that some of the points will receive further scrutiny during consultation for the Environment Agency permitting, but would like to put on the record that there are still gaps. Specifically

a. The 95% capture rate is still only based on models not on real world experience, and therefore cannot be taken simplistically at face value, and we will be pushing for clarity about responses if or when the actual capture rate fails to average at 95%;
b. Although the applicant highlights that with respect to this process, the consenting of biomass burning is not within scope, which therefore takes out the greenhouse gas emissions, this does not alter the **actual emissions to the atmosphere** from both the combustion of the wood pellets and their supply chain.
c. Similarly, that biomass is recognised as **zero-rated** not **zero-carbon** is a bureaucratic convenience, but again, not a reflection of the **actual emissions to the atmosphere** from combustion and supply chain.

Appendix A

Table 2.1 Classes of amines and relevant characteristics for PCC from BAT-for-PCC_v2_EfW-1.pdf, accessed at [redacted]

(summary for amines in aqueous solution, as typically used in PCC applications and pilot tests, based on amine-related references cited in this review) **Type of amine**	**Examples in use**	**Relevant characteristics for PCC**
Primary	MEA	Widely used for other purposes, rapid kinetics, low CO_2 capacity, moderate volatility and can form mists with aerosols, moderate to low stability and resistance to thermal degradation, pure material will not form stable nitrosamines, liquid at all relevant temperatures, easy to reclaim thermally. Proposed for use at increasing concentrations in water (now 35-40% w/w, was 30% w/w) to partially overcome lower CO_2 loading capacity and hence higher regeneration energy requirements than secondary and tertiary amines/blends.
Secondary/ secondary blends	PZ Piperazine	Rapid kinetics, moderate CO_2 capacity, lower volatility compared to MEA but can still form mist with aerosols, good thermal and oxidative stability, as secondary amine the pure material forms nitrosamines, can 'freeze' at lower temperatures so often used as an accelerator in blends with 'slower' amines, reported to be reclaimable thermally (Sexton, 2014) but limited practical evidence available at the time of writing.
PZ + AMP blends		AMP is a sterically-hindered amine with higher capacity and PZ an accelerator in this blend. Non-proprietary version known as CESAR1, with public domain information available (e.g. Brúder, 2011). More toxic, rapid kinetics, high CO_2 capacity, low volatility but can still form mist with aerosols, good thermal and oxidative

		stability, readily forms nitrosamines, limited published evidence on reclaimability to date, precipitation reported for CESAR1 blend at low flue gas temperatures (30$_o$C vs 40$_o$C) (Languille, 2021).
Tertiary/tertiary blends Good capacity but slow kinetics so used in blends	PZ + MDEA blends	PZ is an accelerator for the slower, tertiary amine MDEA in this blend. Rapid kinetics, high CO$_2$ capacity, lower volatility than MEA but can still form mist with aerosols, good thermal and oxidative stability, forms nitrosamines, liquid at all relevant temperatures, may not be easily reclaimable thermally due to the difference between the boiling points of MDEA of 246.1$_o$C and that of PZ of 146$_o$C.