Permitting Decisions – Variation (substantial)

Decision document recording our decision-making process

The variation number is:	EPR/BJ8022IZ/V014
The permit number is:	EPR/BJ8022IZ
The Applicant / Operator is:	VPI Immingham LLP
The Installation is located at:	Immingham CHP Power Plant, Rosper Road, Immingham, North Lincolnshire, DN40 3DZ

The variation is to authorise the retrofit of two trains of Post-Combustion Carbon Capture (PCC) plants treating the flue gas emitted from the Installation's existing two gas turbines (GT1 & GT2) and the two auxiliary boilers (AB1 & AB2), removing carbon dioxide (CO_2) for subsequent compression and storage.

GT1 flue gas will only be directed to PCC plant 1, whilst GT2 flue gas will only be directed to PCC plant 2. The two auxiliary boilers will be manifolded such that either boiler flue gas source can be directed to either PCC plant.

The PCC plants fall under the following EPR Schedule 1 listed activity descriptions:

Section 6.10 Part A(1)(a) - Capture of carbon dioxide streams from an installation for the purposes of geological storage

Hydrogen production is required for conditioning of the CO_2 to remove oxygen prior to transfer of the CO_2 to the pipeline network. Oxygen will be removed in a palladium/platinum deoxygenation unit using hydrogen produced on site by the dissociation of water. The hydrogen production activity falls under the following EPR Schedule 1 listed activity description:

Section 4.2 Part A(1)(a)(i) - Producing inorganic chemicals such as gases: hydrogen

The Installation boundary has been extended to accommodate the PCC plants which will be located to the south of the existing boundary.

When the PCC plants are operational, emissions will be via the dedicated stacks on top of the PCC plant absorber towers at emission points A6 and A7 each at a height of 110m. Otherwise, they will be released to atmosphere via four existing flues at emission points A1, A2, A3, A4 in a 90m high single windshield.

The PCC plants will use an amine-based proprietary solvent (Shell Cansolv DC-103) to strip CO_2 from the flue gas within packed absorber columns, via a weak acid-base reaction.

The flue gas will be cooled by direct contact with recirculating water within the direct contact cooler (DCC). The recirculating water will be cooled against air in the DCC water cooler.

The CO_2-depleted flue gas will then pass through emissions abatement equipment (a water wash and mist eliminator) prior to its release to atmosphere at new emission points to air A6 (PCC plant 1) and A7 (PCC plant 2).

We consider in reaching that decision we have taken into account all relevant considerations and legal requirements and that the Permit will ensure that the appropriate level of environmental protection is provided.

What this document is about

This decision document provides a record of the decision-making process. It summarises the decision-making process to show how the main relevant factors have been taken into account. We have assessed the aspects that are changing as part of this variation, we have not revisited any other sections of the Permit.

It explains how we have considered the Applicant's Application, and why we have included the specific conditions in the variation we are issuing to the Applicant. It is our record of our decision-making process, to show how we have taken into account all relevant factors in reaching our position. Unless the document explains otherwise, we have accepted the Applicant's proposals.

A lot of technical terms and acronyms are inevitable in a document of this nature: we provide a glossary of acronyms near the front of the document, for ease of reference.

Preliminary information and use of terms

We gave the application the reference number EPR/BJ8022IZ/V014. We refer to the application as "the **Application**" in this document in order to be consistent.

The permit number is EPR/BJ8022IZ. We refer to the permit as "the **Permit**" in this document.

The Application was duly made on 21/02/2024.

The Applicant is VPI Immingham LLP. We refer to VPI Immingham LLP as "the **Applicant**" in this document. Where we are talking about what would happen after the variation is granted, we call VPI Immingham LLP "the **Operator**".

The Applicant's facility is located at Immingham, North Lincolnshire, DN40 3DZ. We refer to this as "the **Installation**" in this document.

The structure of this document is as follows:

1. Our decision
2. How we reached our decision
3. The Installation
4. Operation of the Installation – general
5. The Installation’s environmental impact
6. Application of Best Available Techniques
7. Emission limits
8. Monitoring and reporting
9. Environment Agency initiated changes
10. Additional updates/changes requested by the Applicant

Annex 1: Decision checklist

Annex 2: Consultation

Glossary

Baseload	means: (i) as a mode of operation, operating for >4000hrs per annum; and (ii) as a load, the maximum load under ISO conditions that can be sustained continuously, i.e. maximum continuous rating
BAT	best available techniques
BAT-AEEL	BAT Associated Energy Efficiency Level
BAT-AEL	BAT Associated Emission Level
BREF	best available techniques reference document
CCGT	combined cycle gas turbine
CCP	carbon capture plant
CEM	continuous emissions monitor
DLN	dry Low NOx burners
DLN-E	dry Low NOx effective
Emergency use	<500 operating hours per annum
ELV	emission limit value set out in either IED or LCP BAT Conclusions
FEED	front end engineering design
GT	gas turbine
IED	Industrial Emissions Directive 2010/75/EC
LCP	large combustion plant subject to Chapter III of the IED
MEA	mono-ethanolamine
MSUL/MSDL	minimum start-up load/minimum shut-down load
NOx	oxides of nitrogen (NO plus NO_2 expressed as NO_2)
NDMA	N-nitrosodimethylamine
OCGT	open cycle gas turbine
PC	process contribution
PCC	post-combustion carbon capture
PEC	predicted environmental concentration
PM_{10}	particles of 10 microns and smaller
$PM_{2.5}$	particles of 2.5 microns and smaller
SCR	selective catalytic reduction
SNCR	selective non catalytic reduction
UKHSA	UK Health Security Agency

1. Our decision

We have decided to grant the variation to the Applicant. This will allow them to operate the Installation, subject to the conditions in the varied Permit.

We consider that, in reaching that decision, we have taken into account all relevant considerations and legal requirements and that the Permit will ensure that a high level of protection is provided for the environment and human health.

This Application is to operate an Installation which is subject principally to the Industrial Emissions Directive (IED).

The Permit contains many conditions taken from our standard Environmental Permit template including the relevant Annexes. We developed these conditions in consultation with industry, having regard to the legal requirements of the Environmental Permitting Regulations (EPR) and other relevant legislation. This document does not therefore include an explanation for these standard conditions. Where they are included in the Permit, we have considered the Application and accepted the details are sufficient and satisfactory to make the standard condition appropriate. This document does, however, provide an explanation of our use of “tailor-made” or installation-specific conditions, or where our Permit template provides two or more options.

2. How we reached our decision

2.1 Receipt of the Application

The Application was duly made on 21/02/2024. This means we considered it was in the correct form and contained sufficient information for us to begin our determination but not that it necessarily contained all the information we would need to complete that determination, see below.

The Applicant made no claim for commercial confidentiality. We have not received any information in relation to the Application that appears to be confidential in relation to any party.

2.2 Consultation on the Application

We carried out consultation on the Application in accordance with the EPR and our statutory Public Participation Statement. We consider that this process satisfies and frequently goes beyond the requirements of the Aarhus Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters, which are directly incorporated into the IED, which applies to the Installation and the Application. We have also taken into account our obligations under the Local Democracy, Economic Development and Construction Act 2009 (particularly Section 23). This requires us, where we consider it appropriate, to take such steps as we consider appropriate to secure the involvement of representatives of interested persons in the exercise of our functions, by providing them with information, consulting them or involving them in any other way. In this case, our consultation already satisfies the Act’s requirements.

We advertised the Application by a notice placed on our website, which contained all the information required by the IED, including telling people where and when they could see a copy of the Application. The advertising period ran between 22/02/2024 and 19/03/2024.

We made a copy of the Application and all other documents relevant to our determination (see below) available to view on our Citizenspace web-based consultation portal and the public register. Anyone wishing to see these documents could also do so and arrange for copies to be made.

We sent copies of the Application to the following bodies, which includes those with whom we have "Working Together Agreements":

- UK Health Security Agency (UKHSA)
- The Local Authority Director of Public Health
- The Health and Safety Executive (HSE)
- Food Standards Agency (FSA)
- National Grid
- North Lincolnshire Local Authority – Planning and Environmental Departments

These are bodies whose expertise, democratic accountability and/or local knowledge make it appropriate for us to seek their views directly. Note under our Working Together Agreement with Natural England, we only inform Natural England of the results of our assessment of the impact of the Installation on designated Habitats sites.

Further details along with a summary of consultation comments and our response to the representations we received can be found in Annex 2 of this document. We have taken all relevant representations into consideration in reaching our determination.

2.3 Requests for further information

Although we were able to consider the Application duly made, we did in fact need more information in order to determine it and issued requests for information as follows:

Date of request	Details of request	Submission date
16/07/2024	Schedule 5 Notice for further information.	26/09/2024 Points 1 to 4 and 6 to 9: Acid wash, SCR, solvent, capture performance, drainage, monitoring standards (emissions to air), air emissions risk assessment, site plan and flood risk.
		03/10/2024 Point 5, storage of solvent and bulk raw materials.

Date of request	Details of request	Submission date
09/10/2024	Schedule 5 Notice for further information, additional information requested.	10/10/2024 N-amines cumulative assessment model input file.
		05/11/2024 Updated site plan (installation boundary) with site infrastructure.
Further information received	Clarification on effluent discharge at W2.	15/08/2024
20/08/2024	Schedule 5 Notice for further information. (Hydrogen production for CO_2 conditioning)	08/10/2024
24/10/2024	Schedule 5 Notice for further information, additional information requested. Monitoring standards for emission points A2, A6 and A7.	07/11/2024
09/12/2024	Schedule 5 Notice for further information dated 16/07/2024. Additional information requested.	09/12/2024 Model input files for SCR scenario.
18/12/2024	Letter requesting corrections, updates and amendments.	Air emissions tables.
20/02/2025		
15/01/2025	Further information provided.	Human health receptor R2 evidence.
21/01/2025	Schedule 5 Notice for further information dated 16/07/2024. Additional information requested.	04/02/2025 N-amine model, k2 parameter evidence.

Date of request	Details of request	Submission date
19/02/2025	Schedule 5 Notice for further information dated 16/07/2024. Additional information requested.	10/03/2025 Evidence to support the assessment of impacts from amides.
		31/03/2025 17/04/2025 Evidence to support the assessment of impacts from nitrosamines (k values).

A copy of each information notice, email and the response was placed on our public register.

3. The Installation

3.1 Description of the Installation and related issues

The Installation is subject to the EPR because it carries out activities listed in Part 2 of Schedule 1 to the EPR:

Existing activity

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

The Installation consists of a combined heat and power plant (CHP), to supply steam to two adjacent oil refineries with the option for future potential local industries, and electricity to one of the adjacent refineries and to the National Grid. The CHP comprises two LCPs, LCP188 and LCP415.

Proposed activity

Section 6.10 Part A(1)(a) - Capture of carbon dioxide streams from an installation for the purpose of geological storage.

This variation is to authorise the retrofit of two trains of Post-Combustion Carbon Capture (PCC) plants treating the flue gas emitted from the Installation's existing two gas turbines (GT1 & GT2) and the two auxiliary boilers (AB1 & AB2), removing carbon dioxide (CO_2) for subsequent compression and off-shore geological storage (beyond the scope and boundaries of the permitted Installation).

Proposed activity

Section 4.2 Part A(1)(a)(i) - Producing inorganic chemicals such as gases: hydrogen

The gaseous CO_2 stream from the PCC plants will be saturated with water and will contain traces of oxygen which will need to be removed prior to export to the CO_2 pipeline and transport and storage network. Prior to dehydration, oxygen will be removed in a palladium/platinum deoxygenation unit using hydrogen produced on site by the electrolysis of water.

We have specified limits in table S1.2 of the Permit which require the hydrogen production activity to be operated in accordance with the Low Impact Installation criteria specified in the Environment Agency's Environmental Permitting application form at the time the Permit Application was duly made. This was based on the Applicant's justification for abatement of the Application fee for this activity based on the low impact criteria being met.

An installation may also comprise "directly associated activities", which at this Installation are:

Existing directly associated activities

- Processing of raw water to produce water of quality fit for use in LCP188 cooling tower system and process waters from the refineries being demineralised for demineralised water production;
- oil storage;
- surface water drainage;
- water treatment.

Proposed directly associated activities

- raw materials handling and storage;
- solvent reclaiming;
- high pressure compression plant to compress CO_2 prior to exporting it to an offshore storage facility.

Together, these listed and directly associated activities comprise the Installation.

3.2 The site

The Applicant submitted a plan which we consider is satisfactory, showing the site of the Installation and its extent including a new area where the PCC plants are to be located. A plan is included in Schedule 7 to the Permit, and the Operator is required to carry on the permitted activities within the site boundary.

3.3 Key issues in the determination

The key issues during the determination were emissions to air and their impact on human health and the environment as detailed in section 5 of this document.

3.4 The site and its protection

The PCC plants are to be located on land to the south and outside of the existing Installation site boundary, requiring an extension to the Installation boundary.

The additional land is added to the Installation site boundary and the associated Permit. The existing pollution prevention measures for the Installation will be implemented to prevent pollution events, including but not limited to:

- concrete hardstanding across operational areas with kerbs/bunds to ensure that spillages and/or leaks in those areas are contained, manually cleaned up and removed for treatment off-site;
- appropriately designed storage tanks with bunds, sized to either be 110%, where the bund contains a single vessel or 25% of the total volume of all tanks within the bund where multiple tanks are present, in line with the requirements of the CIRIA C736 guidance. In their response to our schedule 5 notice sent 16/07/2024, they confirm that the site risk rating process will be revisited at detailed design at which point the Class 1 classification (low risk, meaning only base level of integrity required) may change or remain the same. A pre-operational condition has been set to address this.
- road tanker unloading areas will have the kerbed/bunded areas sized to hold the full inventory of the tanker, in line with the CIRIA guidance in the event of a full loss of containment;
- closed drainage for operational areas and monitoring of all process emissions from the Installation will be extended and applied to the new operations;
- emergency isolation valves will be put in place to minimise the risk of discharges off-site from any spillages entering the Installation’s surface water drainage system;
- spill kits will be available in suitable locations;
- records related to any potential pollution events, remediation measures and maintenance of pollution prevention measures will be retained at the Installation in line with the existing Installation;
- losses of containment or near misses will be logged, and whether the loss was contained to the site systems (as expected) or managed to enter the underlying soil and groundwater (in which case the clean-up and remediation activities undertaken) will be recorded;
- the Installation will also continue to maintain an infrastructure monitoring log to record the schedule inspection and maintenance of containment systems e.g. solvent storage tank, bunding, and any significant maintenance or repair activities required;
- details of any additional routine inspection and maintenance activities, specific to the PCC plants, will be developed prior to commencement of their operation, and will be in line with industry best practice.

Since the design is preliminary, we have set pre-operational conditions requiring the final design of the containment infrastructure and a drainage plan to be provided.

Under Article 22(2) of the IED, the Applicant is required to provide a baseline report containing at least the information set out in paragraphs (a) and (b) of the Article before starting operation.

The Applicant has submitted a site condition report which includes a report on the baseline conditions as required by Article 22. We have reviewed that report and consider that it adequately describes the condition of the soil and groundwater prior to the start of the PCC plant operations.

The baseline report is an important reference document in the assessment of contamination that might arise during the operational lifetime of the Installation and at cessation of activities at the Installation.

3.5 Closure and decommissioning

Having considered the information submitted in the Application, we are satisfied that the appropriate measures will be in place for the closure and decommissioning of the Installation, as referred to in section 7.5 of the supporting information document provided with the Application. A pre-operational condition requires the Operator to update their Environmental Management System (EMS), and this will include a site closure plan.

At the definitive cessation of activities, the Operator has to satisfy us that the necessary measures have been taken so that the site ceases to pose a risk to soil or groundwater, taking into accounts both the baseline conditions and the site’s current or approved future use. To do this, the Operator will apply to us for surrender of the Permit, which we will not grant unless and until we are satisfied that these requirements have been met.

4 Operation of the Installation – general

4.1 Administrative

The Applicant is the sole Operator of the Installation.

We are satisfied that the Operator is the person who will have control over the operation of the Installation after we issue the variation; and that the Operator will be able to operate the Installation so as to comply with the conditions included in the Permit.

4.2 Management

The Applicant has stated in the Application that they will amend the existing EMS to cover operation of the PCC plants prior to the commencement of operation.

We have set a pre-operational condition requiring the Applicant to address this and provide us with written confirmation. They will also be required to make available all EMS documentation for inspection.

We have also set an improvement condition to report on commissioning of the PCC plants to demonstrate compliance with permit conditions and confirmation that the EMS has been updated accordingly.

We are satisfied that appropriate management systems and management structures will be in place for this Installation, and that sufficient resources are available to the Operator to ensure compliance with all the Permit conditions.

4.3 Accident management

The Applicant has not submitted an Accident Management Plan. However, having considered the other information submitted in the Application, we are satisfied that appropriate measures will be in place to ensure that accidents that may cause pollution are prevented but that, if they should occur, their consequences are minimised. An updated Accident Management Plan for the Installation, including the proposed PCC plants, will form part of the EMS and must be in place prior to commissioning as required by a pre-operational condition.

4.4 Flood risk management

The site lies within flood zone 3 which is land at risk of flooding, assuming no flood defences exist, for a flood with a 0.5% chance of occurring in any year for flooding from the sea. The site is at tidal flood risk.

Our Hazard Mapping shows the consequences should a breach or overtopping of our sea defences occur, including the likely flood depths, velocities and overall hazard that could impact the site over its lifetime.

The site has a current day and future hazard classification of 'danger to most/all' as defined in Research & Development report FD2320 'Flood Risk Assessment Guidance for New Development'. It could experience flood depths of 1.6m and above arising from a breach in the defences during a flood that has a 0.5% chance of occurring in any one year up to 2115; this depth band also applies for the 2115 0.1% breach scenario.

The site has a future hazard classification of 'danger to all' as defined in Research & Development report FD2320 'Flood Risk Assessment Guidance for New Development'. The site is not affected by modelling for the current day overtopping scenarios. It could experience flood depths of 1.6m and above arising from overtopping of the defences during a flood that has a 0.5% chance of occurring in any one year up to 2115; this depth band also applies for the 2115 0.1% breach scenario.

In their response to our Schedule 5 Notice for further information dated 16/07/2024, they confirmed that in a flood scenario, the site would be evacuated, except for a small number of people required to perform essential services. A safe refuge (greater than 3m above grade) will be provided within the existing Installation boundary, which is well above the potential 1.6m flooding scenario identified.

4.5 Operating techniques

We have specified that the Applicant must operate the Installation in accordance with a number of documents provided with the Application and as part of further information requests.

These documents describe the techniques that will be used for the operation of the Installation that have been assessed by the Environment Agency as BAT; they form part of the Permit through Permit condition 2.3.1 and table S1.2. The table has been updated to include the operating techniques relevant to the operation of the PCC plants.

5. The Installation’s environmental impact

Regulated activities can present different types of risk to the environment, these include noise and vibration, accidents, fugitive emissions to air and water, as well as point source releases to air, discharges to ground or groundwater, global warming potential and generation of waste and other environmental impacts. Consideration may also have to be given to the effect of emissions being subsequently deposited onto land (where there are ecological receptors). The key factors relevant to this determination are discussed in this and other sections of this document.

For an activity of this kind, the principal emissions are those to air, although we also consider those to land and water.

The next sections of this document explain how we have approached the critical issue of assessing the likely impact of the emissions to air from the PCC plants absorber stacks on human health and the environment.

The Applicant’s Air Quality Assessment (AQA) compares the predicted impacts of the future operation (future assessment) to the current CO_2 unabated operation (baseline assessment):

Baseline assessment - considered the impact of the existing combustion emissions from GT1, GT2 and auxiliary boilers 1 (AB1) and 2 (AB2) under normal operating conditions, with all sources assumed to be operating for 8,760 hours per year, as this represents the worst-case for annual average impacts. The existing combustion emissions from these sources are released to air via dedicated flues at emission points A1 to A4, held within a single windshield (stack), which is 90m high. The assessment is based on the limits set in the Permit.

There will be no change to emissions from GT3, so this has not been included in the assessment as it is already considered and taken into account in the existing background concentrations used for the assessment.

Future assessment - PCC plants under normal operating conditions i.e. exhaust gases from GT1, GT2, AB1 and AB2 being abated by the PCC plants, operating for up to 8,760 hours per year. Emissions from these sources are released to air via dedicated stacks at emission points A6 and A7, which are 110m high.

Following commissioning of the PCC plants, the normal mode of operation for GT1, GT2, AB1 and AB2 will be the CO_2 abated mode, with carbon capture taking place. The existing flue gases from emission points A1 to A4 will be diverted from the existing emission points to the PCC plants, where the CO_2 will be removed. They will then be released via two new emissions points located on top of the PCC plant absorber columns at emission points A6 and A7. These emission points will be the primary source of emissions to air once the PCC plants become operational, with the emission points A1 to A4 not being used under normal operation. The existing emission points will remain, however, and will essentially become bypass vents when the PCC plants are not operational, see above.

GT1 flue gas will only be treated by PCC plant 1, with flue gas released via emission point A6.

GT2 flue gas will only be treated by PCC plant 2, with flue gas released via emission point A7.

The two auxiliary boilers AB1 and AB2 will be manifolded such that either boiler flue gas source can be treated by either PCC plant 1 or 2, with flue gas released via emission points A6 or A7.

The existing permit emission limits for the GTs and the auxiliary boilers will continue to be applicable to the emissions from the PCC plants once these become operational.

Emissions associated with the amine solvent are based on concentrations provided by the technology provider.

5.1 Assessment methodology

5.1.1 Application of Environment Agency web guide for air emissions risk assessment

A methodology for risk assessment of point source emissions to air, which we use to assess the risk of applications we receive for permits, is set out in our web guide and has the following steps:

- describe emissions and receptors;
- calculate process contributions;
- screen out insignificant emissions that do not warrant further investigation;
- decide if detailed air modelling is needed;
- assess emissions against relevant standards;
- summarise the effects of emissions.

The methodology uses a concept of “process contribution (PC)”, which is the estimated concentration of emitted substances after dispersion into the receiving environmental media at the point where the magnitude of the concentration is greatest. The guidance provides a simple method of calculating PCs primarily for screening purposes and for estimating PCs where environmental consequences are relatively low. It is based on using dispersion factors. These factors assume worst case dispersion conditions with no allowance made for thermal or momentum plume rise and so the PCs calculated are likely to be an overestimate of the actual maximum concentrations. More accurate calculation of PCs can be achieved by mathematical dispersion models, which take into account relevant parameters of the release and surrounding conditions, including local meteorology.

5.1.2 Use of air dispersion modelling

For this type of Application, we require the Applicant to submit a full air dispersion model as part of their Application, for the key pollutants. Air dispersion modelling enables the PC to be predicted at any environmental receptor that might be impacted by the plant.

Once short-term and long-term PCs have been calculated in this way, they are compared with Environmental Quality Standards (EQS).

Where an EU EQS exists, the relevant standard is the EU EQS. Where an EU EQS does not exist, our guidance sets out a National EQS (also referred to as Environmental Assessment Level - EAL) which has been derived to provide a similar level of protection to Human Health and the Environment as the EU EQS levels. In such cases, we use the National EQS standard for our assessment.

National EQSs do not have the same legal status as EU EQSs, and there is no explicit requirement to impose stricter conditions than BAT in order to comply with a national EQS. However, national EQSs are a standard for harm and any significant contribution to a breach is likely to be unacceptable.

PCs are considered i**nsignificant** if:

- the **long-term** PC is less than **1%** of the relevant EQS; and
- the **short-term** PC is less than **10%** of the relevant EQS.

The **long-term** 1% PC insignificance threshold is based on the judgements that:

- it is unlikely that an emission at this level will make a significant contribution to air quality;
- the threshold provides a substantial safety margin to protect health and the environment.

The **short-term** 10% PC insignificance threshold is based on the judgements that:

- spatial and temporal conditions mean that short-term PCs are transient and limited in comparison with long-term PCs;
- the threshold provides a substantial safety margin to protect health and the environment.

Where an emission is screened out in this way, we would normally consider that the Applicant's proposals for the prevention and control of the emission to be BAT. That is because if the impact of the emission is already insignificant, it follows that any further reduction in this emission will also be insignificant.

However, where an emission cannot be screened out as insignificant, it does not mean it will necessarily be significant.

For those pollutants which do not screen out as insignificant, we determine whether exceedances of the relevant EQS are likely. This is done through detailed audit and review of the Applicant's air dispersion modelling taking background concentrations and modelling uncertainties into account. Where an exceedance of an EU EQS is identified, we may require the Applicant to go beyond what would normally be considered BAT for the Installation or we may refuse the application if the Applicant is unable to provide suitable proposals. Whether or not exceedances are considered likely, the Application is subject to the requirement to operate in accordance with BAT.

This is not the end of the risk assessment, because we also take into account local factors (for example, particularly sensitive receptors nearby such as Sites of Special Scientific Interest (SSSIs), Special Areas of Conservation (SACs) or Special Protection Areas (SPAs). These additional factors may also lead us to include more stringent conditions than BAT.

If, as a result of reviewing the risk assessment and taking account of any additional techniques that could be applied to limit emissions, we consider that emissions **would cause significant pollution**, we would refuse the Application.

5.2 Assessment of impact on air quality

The Applicant's assessment of the impact on air quality is set out in Appendix F - Air Impact Assessment, dated December 2023, of the Application. The assessment comprises:

- baseline and future assessment, as described above;
- dispersion modelling of emissions to air and the impact on human health receptors/local air quality from the operation of the PCC plants;
- a study of the impact of emissions on nearby sensitive conservation sites.

This section of the decision document deals primarily with the dispersion modelling of emissions to air from the PCC plants and their impact on local air quality. The impact on conservation sites is considered in section 5.3 of this document.

The Applicant has assessed the PCC plants potential emissions to air against the relevant air quality standards, and the potential impact upon local conservation sites and human health. These assessments predict the potential effects on local air quality from the PCC plants stack emissions using the ADMS (Atmospheric Dispersion Modelling System) dispersion model (version 6), which is a commonly used computer model for regulatory dispersion modelling.

The ADMS model developers, Cambridge Environmental Research Consultants Limited (CERC), have generated a specific amine chemistry module for use with ADMS software, for assessment of emissions of amines and their atmospheric degradation products. The ADMS amine chemistry module is the only commercially available software that can be used to evaluate potential impacts on air quality from amines and amine degradation. The model calculates the rate of amine degradation taking into account the reaction of amines with other species present in the exhaust gas (i.e. nitrogen dioxide (NO_2)) and also with hydroxyl radicals in the atmosphere. Whilst the ADMS model itself has been validated, the specific amines module has not been, and therefore the results should be regarded as indicative rather than definitive.

The model used five years of meteorological data between 2017 and 2021 collected from the weather station at Humberside Airport, which is 9.5 km south-west of the Installation. The impact of the terrain surrounding the site upon plume dispersion was considered in the dispersion modelling.

The Applicant's air impact assessments, and the dispersion modelling upon which they were based, employed the following conservative assumptions:

- emission concentrations for the process are calculated based on the use of IED limits, BAT Associated Emission Level (AEL) concentrations, or maximum envisaged emission rates from the technology provider; in practice annual average rates would be below this to enable continued compliance with environmental permit requirements;

- conservative assumptions on the amine and N-amine species likely to be emitted (assumes total N-amine is the most toxic species);
- maximum annual operation for the plant configuration assessed for 8,760 hours;
- reporting of the worst-case results from the five years of meteorological data modelled.

We are in agreement with this approach. The assumptions underpinning the model have been checked and are reasonably precautionary.

The Applicant provided us with modelled output showing the concentration of key pollutants at a number of specified locations within the surrounding area.

The way in which the Applicant used dispersion models, its selection of input data, use of background data and the assumptions it made have been reviewed by the Environment Agency to establish the robustness of the Applicant's air impact assessment. The output from the model has then been used to inform further assessment of health impacts and impact on habitats and conservation sites.

Our review of the Applicant's assessment is set out in the relevant sections below.

The Applicant's modelling predictions are summarised in the following sections.

5.2.1 Assessment of air dispersion modelling outputs

The modelling predictions are summarised in the tables below.

The tables below show the baseline maximum concentrations of pollutants at a human health receptor. Where emissions screen out as insignificant, the background pollutant levels are not considered within the assessment in accordance with our H1 screening process. Where we take the background levels into account, we combine these with the PC to determine the predicted environmental concentration (PEC) and assess the headroom between the PEC and the EQS as shown below.

Whilst we have used the Applicant's modelling predictions in the tables below, we have made our own verification calculation of the percentage PC and PEC. These are the numbers shown in the tables below and so may be very slightly different to those shown in the Application. Any such minor discrepancies do not materially impact on the conclusions.

5.2.1a Baseline - The modelling predicted maximum pollutant concentrations at a human health receptor

Baseline – maximum at a human health receptor					
Pollutant	EQS/EAL (µg/m³)	PC (µg/m³)	PC as % of EQS/ EAL	PEC (µg/m³) (Background + PC)	PEC as % of EQS/EAL
Nitrogen dioxide (NO_2) Annual mean	40	0.9	2.3	15.9	39.8
NO_2 1 hour mean	200	17.2	8.6	-	-

Baseline – maximum at a human health receptor					
Pollutant	EQS/EAL (µg/m³)	PC (µg/m³)	PC as % of EQS/ EAL	PEC (µg/m³) (Background + PC)	PEC as % of EQS/EAL
Carbon monoxide (CO) 1 hour mean	30,000	105.8	0.4	-	-
CO 8 hour mean	10,000	84.1	0.8	-	-
Particulate matter (PM_{10}) Note 1 Annual mean	40	0.013	0.03	-	-
PM_{10} Note 1 24 hour mean	50	0.1	0.2	-	-
$PM_{2.5}$ Note 2 Annual	20	0.013	0.07	-	-
Sulphur dioxide (SO_2) 15 minute mean	266	3.2	1.2	-	-
SO_2 1 hour mean	350	2.9	0.8	-	-
SO_2 24 hour mean	125	0.8	0.6	-	-
Note 1: Particles of 10 microns and smaller. Note 2: Particles of 2.5 microns and smaller.					

For the baseline scenario, all emissions screen out as insignificant (PC is <1% of the long-term EQS/EAL or <10% of the short-term EQS/EAL), with the exception of long-term NO_2.

The long-term NO_2 was over 1% of the EQS so we also considered the background NO_2 level. When taking this into account there is adequate headroom between the PEC and EQS to indicate that it is unlikely that there will be an exceedance of an EQS.

5.2.1b Future - The modelling predicted maximum pollutant concentrations at a human health receptor

Future – maximum at a human health receptor						
Pollutant	EQS/EAL (µg/m³)	PC (µg/m³)	PC as % of EQS/EAL	PEC (µg/m³) (Background + PC)	PEC as % of EQS	Change in PC over baseline %
NO_2 Annual mean	40	1.8	4.5	16.8	42	+2.2
NO_2 1 hour mean	200	30.7	15.4	60.7	30.4	+6.8
CO 1 hour mean	30,000	271.6	0.9	-	-	+0.5
CO 8 hour mean	10,000	137.7	1.4	-	-	+0.6
PM_{10} Note 1 Annual mean	40	0.03	0.1	-	-	+0.1
PM_{10} Note 1 24 hour mean	50	0.17	0.3	-	-	+0.1
$PM_{2.5}$ Note 2 Annual	20	0.03	0.2	-	-	+0.1
SO_2 15 minute mean	266	6.1	2.3	-	-	+1.1
SO_2 1 hour mean	350	5.1	1.5	-	-	+0.7
SO_2 24 hour mean	125	1.2	1.0	-	-	+0.4
NH_3 Annual mean	180	0.1	0.1	-	-	-

Future – maximum at a human health receptor						
Pollutant	EQS/EAL (µg/m³)	PC (µg/m³)	PC as % of EQS/EAL	PEC (µg/m³) (Background + PC)	PEC as % of EQS	Change in PC over baseline %
NH_3 1 hour mean	2,500	2.6	0.1	-	-	-
Amine 1 [Note 6] and 3 [Note 8] 24 hour mean	100 [Notes 5, 10]	0.1	0.1	-	-	-
Amine 1 [Note 6] and 3 [Note 8] Hourly mean	400 [Note 10]	0.3	0.1	-	-	-
Amine 2 [Note 7] 24 hour mean	17 [Notes 4, 10]	0.01	0.1	-	-	-
Amine 2 [Note 7] Hourly mean	75 [Notes 4, 10]	0.03	0.04	-	-	-
Piperazine (Amine 2 [Note 7]) 24 hour mean	15 [Note 4]	0.01	0.07	-	-	-
Amine 1 [Note 6] + Amine 2 [Note 7] + Amine 3 [Notes 8 & 9] 24 hour mean	15	0.1 + 0.01 = 0.11	0.73	-	-	-
Acetaldehyde Annual mean	370	0.01	<0.01	-	-	-
Acetaldehyde 1 hour mean	9,200	0.3	<0.01	-	-	-
Formaldehyde Annual mean	5	0.004	0.1	-	-	-

Future – maximum at a human health receptor						
Pollutant	EQS/EAL (µg/m^3)	PC (µg/m^3)	PC as % of EQS/EAL	PEC (µg/m^3) (Background + PC)	PEC as % of EQS	Change in PC over baseline %
Formaldehyde 30 minute mean	100	0.01	0.01	-	-	-
Amide Annual mean	0.05 $^{\text{Note 3}}$	0.002	4	-	-	-
Amide Hourly mean	18	0.04	0.2	-	-	-

Note 1: Particles of 10 microns and smaller.

Note 2: Particles of 2.5 microns and smaller.

Note 3: Amides were assessed against the acrylamide EAL, see below. The Applicant initially incorrectly applied the EAL for acrylamide of 0.6 µg/m^3 instead of the lower 0.05 µg/m^3. This means that the amide emission no longer screens out as insignificant.

Note 4: Refer to Environment Agency assessment conclusions below.

Note 5: If we apply the much lower EAL for piperazine, the emission still screens out as insignificant with the PC 0.67% of the EAL.

Note 6: Amine 1 - 1-Piperazineethanol

Note 7: Amine 2 - Piperazine

Note 8: Amine 3 - 1,4-Piperazinediethanol

Note 9: For amine 3, refer to section 5.2.1c of this document.

Note 10: EAL derived proposed by the Applicant but not endorsed by the Environment Agency. Refer to the Environment Agency assessment conclusions below for additional details.

For the future scenario, all emissions screen out as insignificant (PC is <1% of the long-term EQS/EAL or <10% of the short-term EQS/EAL), with the exception of NO_2 and amide.

Where emissions screen out as insignificant, we consider the Applicant's proposals for preventing and minimising the emissions of these substances to be BAT for the Installation.

NO_2

For NO_2, the change in PC over the baseline assessment is 2.2% and 6.8% respectively, for the long and short-term assessments.

The impact on air quality from NO_2 emissions has been assessed against the EQS of 40 $\mu g/m^3$ as a long-term annual average and a short-term hourly average of 200 $\mu g/m^3$. The model assumes a 70% NO_x to NO_2 conversion for the long term and 35% for the short-term assessment in line with Environment Agency guidance on the use of air dispersion modelling.

The above table shows the maximum long-term PC is 4.5% of the EQS and the maximum short-term PC is 15.4% of the EQS. There is adequate headroom between the PEC and EQS to indicate an exceedance is unlikely.

Total amides

Total amides were assessed against the EAL for acrylamide. Acrylamide is classified as a CMR (carcinogen, mutagen, reproductive toxicant) chemical, whereas, according to the information provided by the Applicant, the amides formed from the degradation of the CANSOLV amines are not considered to be CMR chemicals. They therefore considered that the use of the acrylamide EAL was very conservative.

The impact on air quality from amide emissions has been assessed against the lower acrylamide EAL of 0.05 $\mu g/m^3$ as a long-term annual average.

The above table shows the maximum long-term PC is 4% of the EAL which occurs at R2.

Amide levels are not routinely monitored in the UK, therefore in the absence of data the Applicant has assumed background concentrations to be zero. On this basis there is likely to be adequate headroom between the PEC and EAL to indicate an exceedance is unlikely. We did however ask the Applicant to consider cumulative impacts, see below.

Total amides cumulative assessment

We also asked the Applicant to consider the impacts from total amides in combination with other carbon capture plants proposed and in development in the area. The worst-case PC from the Phillips 66 carbon capture plant was 0.0001 $\mu g/m^3$ which occurs at R8. This is 0.2% of the acrylamide annual mean EAL and therefore can be considered to be insignificant.

These worst-case concentrations are predicted to occur at different receptors, however when considered together they represent only 4.2% of the acrylamide annual mean EAL and therefore are not considered to be significant.

Whilst it is recognised that there are plans emerging for other carbon capture plants in the vicinity of the VPI and Phillips 66 plants, such as the proposed Stallingborough CCS enabled power station and the Humber H2ub Blue Hydrogen project, these schemes are not as developed as the Humber Zero project and therefore there is limited information available on emissions from these schemes. Specifically, the carbon capture solvent that will be used for other schemes is not yet known and whether the degradation products would include amides. It is considered that as these schemes progress, they will be required to assess cumulative impacts with the Humber Zero project (and any other planned schemes) at the planning/permitting stage.

5.2.1c Environment Agency assessment conclusions

For human health, our checks indicate that PCs and predicted changes in PCs are either below 1% and 10% of the long and short-term EQSs, or PECs are below the EQS.

Amide levels are not routinely monitored in the UK, therefore in the absence of data the Applicant has assumed background concentrations to be zero. We did however ask the Applicant to consider cumulative impacts, see above. We conclude that there is likely to be adequate headroom between the PEC and EAL to indicate an exceedance is unlikely.

Therefore, we consider the Applicant's proposals for preventing and minimising NO_2 and amide emissions are BAT for the Installation. We address this in further detail in section 6 of this document.

At the time of submitting the Application, there were no EALs for amines 1 (1-Piperazineethanol), 2 (piperazine, see below) or 3 (1,4-Piperazinediethanol).

For amines 1 and 3, the Applicant used the available EALs for monoethanolamine (MEA) as a proxy. They suggested that more stringent EALs for amine 2 would be appropriate, thus derived their own EALs. The derived 24-hour annual mean EAL is 17 µg/m^3 and the 100th percentile 1-hour mean EAL is 75 µg/m^3.

We consulted the UKHSA on the proposed use of the MEA EALs for amines 1 and 3 and on the EAL derived by the Applicant for amine 2. According to the advice received from the UKHSA toxicologists, we considered that the Applicant had not provided sufficient evidence to justify the proposed EALs. Refer to Annex 2 of this document for UKHSA comments on this matter.

Working with the UKHSA, the Environment Agency has derived a long-term EAL for piperazine of 0.015 mg/m^3 (15 μg/m^3) averaged over 24 hours to protect public health. This value is considered by us to be protective of toxic effects including from short-term exposure and potential carcinogenicity resulting from in vivo conversion of piperazine to N-nitrosopiperazine following inhalation.

This piperazine long-term EAL has since been published following public consultation (Environmental Assessment Levels for the amine-based carbon capture process - GOV.UK).

Our derived EAL for piperazine of 15 μg/m^3 is not that dissimilar to the one proposed by the Applicant for amine 2 (piperazine) of 17 μg/m^3, although the methodology and the explanation given by the Applicant were not as thorough as the evidence gathered and methodology used in our dossier.

On this basis, we have decided that we do not need to ask for any additional information or clarification in relation to amine 2 (piperazine), as it would be immaterial to our permitting decision.

With regard to amine 1 and 3, the UKHSA advised that, as there is closer structural similarity of amine 1 and amine 3 to amine 2 (piperazine), they considered that piperazine is a more appropriate substance to read across from than MEA for the other two amines.

We have therefore added up the total PCs of amines 1, 2 and 3 and compared them against the EAL for piperazine: as these are below 1% of the EAL we have concluded that impacts on human health associated with these emissions are insignificant.

We have included an improvement condition requiring the Operator to compare actual emissions from the PCC plants once they are operating with the predicted emissions provided with the Application and if necessary to carry out an impact assessment.

We have also set an improvement condition to report on commissioning of the PCC plants including a summary of the environmental performance of the PCC plants as installed against the design parameters and risk assessments.

5.2.1d Future - The modelling predicted maximum N-amines concentrations at a human health receptor

The Applicant assessed the impacts from degradation products (nitramines and nitrosamines, referred to as N-amines in the following) associated with the emissions of amines from the operations of the absorber columns.

We are satisfied that the Applicant's amines transformation model incorporates several conservative assumptions based on the proposed emission parameters and the best available knowledge at the time of the assessment. They followed our guidelines (*AQMAU recommendations for the assessment and regulation of impacts to air quality from amine-based post-combustion carbon capture plants. AQMAU-C2025-RP01. November 2021. Available at AQMAU-C2025-RP01.pdf (ukccsrc.ac.uk)*) and risk assessment guidance (*Guidance: Air emissions risk assessment for your environmental permit. Available at Air emissions risk assessment for your environmental permit - GOV.UK (www.gov.uk) [Accessed in April 2024]*) to address uncertainty from the use of the ADMS amines chemistry model.

The Environment Agency Risk Assessment Guidance includes EALs for MEA (a primary amine) and N-nitrosodimethylamine (NDMA) (a stable nitrosamine). Amines, nitrosamine and nitramines are not routinely monitored in the UK, therefore in the absence of data the Applicant assumed background concentrations to be zero.

NDMA is one of the most potent nitrosamines in terms of carcinogenic potential and is one of the most widely studied of the nitrosamines.

The Applicant assessed the process contributions of N-amines against the NDMA EAL. We are satisfied that this approach is conservative.

In their response provided 31/03/2025 to our Schedule 5 Notice for further information dated 19/02/2025, the Applicant provided an updated N-amine assessment. The N-amines assessment was updated using revised rate constants, in line with a recent communication from the technology provider. No other model parameters were changed from those presented in the original assessment provided in Appendix F of the Main Supporting Document.

The following tables show the maximum predicted PCs against the worst-case NDMA EAL.

Total N-amine 1 impacts from amine 1 and N-amine 1 emissions - assessment results

Future – maximum at a human health receptor					
Pollutant	EAL (ng/m^3)	Nitrosamine 1 PC (ng/m^3)	Nitramine 1 PC (ng/m^3)	Total N-amines 1 Note 3 PC (ng/m^3)	Total N-amines 1 PC as % of EAL
NDMA Annual mean	0.2	0.080	0.026	0.106	53 Note 1
		0.053	0.043	0.096	48 Note 2
Note 1: R2 receptor, unoccupied residence, understood to be being demolished. Note 2: R8 receptor. Note 3: N-amine 1 (4-Nitroso-1-piperazineethanol).					

The results for the total impacts of amine 1 and N-amine 1 emissions indicate that PCs at receptor locations are lower than those presented in the original assessment and are less than 70% of the very conservative EAL for NDMA.

The worst-case impacts are experienced at receptor R2 (a single residential property on Station Road which is currently vacant, owned by Able Humber Ports Limited and is proposed to be demolished). Impacts at the next worst-case receptor, R8, are lower, with a PC of 48% of the EAL.

Total N-amine 2 impacts from amine 2 and N-amine 2 emissions - assessment results

Future – maximum at a human health receptor					
Pollutant	EAL (ng/m³)	Nitrosamine 2 PC (ng/m³)	Nitramine 2 PC (ng/m³)	Total N-amines 2 [Note 3] PC (ng/m³)	Total N-amines 2 PC as % of EAL
NDMA Annual mean	0.2	0.024	0.004	0.028	14 [Note 1]
		0.011	0.006	0.017	9 [Note 2]
Note 1: R2 receptor, unoccupied residence, understood to be being demolished. Note 2: R8 receptor. Note 3: N-amine 2 (1-nitrosopiperazine).					

The results for the total impacts of amine 2 and N-amine 2 emissions indicate that PCs at receptor locations are within the very conservative EAL for NDMA.

The worst-case impacts are experienced at receptor R2 (see above). Impacts at the next worst-case receptor, R8, are lower, with a PC of 9% of the EAL.

Total N-amine assessment results

The overall impact of the releases of atmospheric N-amines generated from amine 1 and amine 2 and the direct N-amine releases are shown in the table below and compared against the very conservative EAL for NDMA.

Future – maximum at a human health receptor					
Pollutant	EAL (ng/m³)	Nitrosamine PC (ng/m³)	Nitramine PC (ng/m³)	Total N-amines PC (ng/m³)	Total N-amines PC as % of EAL
NDMA Annual mean	0.2	0.104	0.03	0.134	67 [Note 1]
		0.064	0.049	0.113	57 [Note 2]
Note 1: R2 receptor, unoccupied residence, understood to be being demolished. Note 2: R8 receptor.					

The results for the total N-amine impacts for the future operation of the Installation indicates that PCs at receptor locations are below 70% of the conservative EAL for NDMA.

The worst-case impacts are experienced at receptor R2, with a PC of 67% of the EAL. It should be noted that this result occurs at a vacant property. Impacts at the next worst-case receptor, R8, are lower, with a PC of 57% of the EAL.

Given the conservative assumptions used in the assessment, and that information currently available indicates that the Cansolv N-amines are less toxic than NDMA, the assessment carried out indicates that the N-amine PCs predicted at the receptor locations are unlikely to result in impacts to human health.

Total N-amine assessment results cumulative assessment

This proposal is part of the wider Humber Zero Project (HZP), which consists of two proposed developments to install PCC plants and associated facilities located at VPI Immingham CHP Power Plant and the adjacent Phillips 66 Humber Refinery.

We asked the Applicant to provide a cumulative assessment of emissions of nitrosamines, taking into account the nearby proposed Phillips 66 carbon capture project and, if possible, other carbon capture projects planned in the area.

An assessment was provided on 31/03/2025 in their response to our Schedule 5 Notice for further information dated 19/02/2025, and is summarised below:

Since the submission of the initial Application, the technology provider has identified that the value of the k2 parameter, previously used for the amine dispersion modelling (provided as Appendix F of the Main Supporting Document), resulted in an overprediction of the N-amine impacts from the VPI (and Phillips 66) PCC plants.

They therefore re-assessed the impact from N-amines (see above) using revised rate constants in the model.

Section 6.3 of Appendix F is therefore superseded by the new results which are presented in the 31/03/2025 response. This has been used as the new basis for the cumulative assessment.

The assessment considers the impacts from VPI and Phillips 66 only. Whilst they recognise that there are emerging plans for other carbon capture plants in the vicinity, such as the proposed Stallingborough CCS enabled power station and Humber H2ub Blue Hydrogen project, these schemes are not as developed as the Humber Zero project and therefore there is limited information available on the N-amine emissions from these schemes. Specifically, the carbon capture solvent that will be used for other schemes is not yet known.

The overall impact at R2 and R8 of the releases of atmospheric N-amines (from VPI Immingham CHP Power Plant and the adjacent Phillips 66 Humber Refinery) generated from amine 1 and amine 2 and the direct N-amine releases are shown in the table below and compared against the very conservative EAL for NDMA.

<table>
<tr><th colspan="6">Future – maximum at a human health receptor</th></tr>
<tr><th>Pollutant</th><th>EAL (ng/m^3)</th><th>Total VPI N-amines PC (ng/m^3)</th><th>Total Phillips 66 N-amines PC (ng/m^3)</th><th>Cumulative N-amines PC (ng/m^3)</th><th>Cumulative N-amines PC as % of EAL</th></tr>
<tr><td rowspan="2">NDMA
Annual mean</td><td rowspan="2">0.2</td><td>0.134</td><td>0.019</td><td>0.153</td><td>77 [Note 1]</td></tr>
<tr><td>0.113</td><td>0.041</td><td>0.154</td><td>77 [Note 2]</td></tr>
<tr><td colspan="6">Note 1: R2 receptor, unoccupied residence, understood to be being demolished.
Note 2: R8 receptor.</td></tr>
</table>

The cumulative impact of the two schemes represents 77% of the NDMA EAL at the worst-case receptors. Given the worst-case assumptions used in the assessment, as detailed in Appendix F of the Main Supporting Document, it is considered that the N-amine impacts from both schemes would not result in an exceedance of the very conservative NDMA EAL used for the assessment.

5.2.1e Environment Agency assessment conclusions

Amine 1 and amine 2 are secondary amines and can potentially form stable nitrosamines and nitramines (N-amines). The Applicant states that there is no nitrosamine associated with amine 3 as it “is a tertiary amine that does not form stable nitrosamines”. We note that tertiary amine groups do not have any nitrogen-bound hydrogens available for abstraction, however, available publications (*In tertiary amines the initial hydrogen abstraction can only take place from the alkyl chain, and subsequent formation of nitrosamines and nitramines necessitate C–N bond scission.” Nielsen, C.J., Herrmann, H. and Weller, C. (2012); Atmospheric chemistry and environmental impact of the use of amines in carbon capture and storage (CCS), Chemical Society Reviews, 41(19), p.6684, doi:https://doi.org/10.1039/c2cs35059a*) at the time of this audit indicate that a nitrosamine forming reaction occurs via a different mechanism, yet there is limited published data for tertiary amine reaction constants. Given the low proportion of amine 3 released from the stack, we accept this approach.

At the time of the audit, there were no EALs for the N-amines potentially formed from amine 1 and amine 2. The Applicant presents evidence on the lower toxicity of the N-amines from amine 1 and amine 2 and assessed against the NDMA EAL and these form the basis of our decision-making. Refer to Annex 2 of this document for UKHSA comments on this matter.

Regarding the N-amines cumulative assessment, we are satisfied that it is reasonable to consider just VPI Immingham CHP Power Plant and the adjacent Phillips 66 Humber Refinery, since there is limited information available on the N-amine emissions from other projects in the area.

Maximum predicted N-amine (nitrosamine and nitramine) PCs are predicted to be below the NDMA EAL. The Applicant’s maximum N-amine PC from VPI alone is 67% of the EAL, while the maximum in-combination PC is 77% of the EAL.

We agree with the Applicant’s conclusions that the emissions are unlikely to exceed the NDMA EAL.

Therefore, we consider the Applicant’s proposals for preventing and minimising N-amines emissions is BAT for the Installation. We address this in further detail in section 6 of this document.

We have included an improvement condition requiring the Operator to compare actual emissions from the PCC plants with those provided with the Application and if necessary to carry out an impact assessment.

We have also set an improvement condition to report on commissioning of the PCC plants to include a summary of the environmental performance of the PCC plants as installed against the design parameters and risk assessments.

5.4 Impact on Habitats sites, SSSIs and non-statutory conservation sites

5.4.1 Sites Considered

The following **habitat** (i.e. Special Areas of Conservation (SAC), Special Protection Areas (SPA) and Ramsar) site is located within 15 km of the Installation. We have included the Applicant’s identifiers for each site.

- Humber Estuary (E1a to E1f)

The following Sites of Special Scientific Interest (**SSSI**) are located within 15 km of the Installation:

- Humber Estuary (E1a to E1f)
- North Killingholme Haven Pits (E2)
- Swallow Wold (E3)
- Wrawby Moor (E4)

The following **non-statutory** local wildlife sites (**LWS**) and Sites of Importance for Nature Conservation (**SINC**) are located within 2 km of the Installation:

- Eastfield Road Railway Embankment LWS (E5)
- Burkinshaws Covert LWS (E6)
- Rosper Road Pools LWS (E7)
- Chase Hill Wood LWS (E8)
- Mayflower Wood Meadow LWS (E9)
- Homestead Park Pond LWS / SINC (E10)
- Eastfield Road Pit SINC (E11)

5.4.2 Habitats/SSSI Assessment

The following details the results of the Applicant’s air quality modelling assessment of the impacts from the baseline (existing operations) and future operations on the Humber Estuary, which is the worst-case location for impacts for all relevant ecological receptors:

5.4.2a Baseline - The modelling predicted maximum pollutant concentrations at the Humber Estuary receptor

Baseline – maximum at the Humber Estuary						
Pollutant	EQS/EAL (µg/m³)	Back-ground (µg/m³)	PC (µg/m³)	PC as % of EQS/EAL	PEC (µg/m³)	PEC as % EQS/EAL
Direct Impacts Note 1						
NO_x Annual mean	30	20	1.18	3.9	23.9	70.6
NO_x Daily mean	75	30	12	16	44.6	56
SO_2 Annual mean	20	-	0.09	0.5	-	-
Deposition Impacts Note 1						
Nitrogen deposition (kg N/ha/yr) Note 3 Annual mean	20	-	0.1	0.5	-	-
Acid deposition (Keq/ha/yr) Note 2 Annual mean	Min CL Min N – 0.285 Min CL Max N – 1.033 Min CL Max S – 0.748	-	N: 0.0013 S: 0.0016	0.5	-	-

Note 1: Direct impact units are µg/m³ and deposition impact units are kg N/ha/yr or Keq/ha/yr.

Note 2: For acidification, there is no critical load assigned to the Humber Estuary in APIS. We have included the most impacted receptor with a critical load, which is Wrawby Moor SSSI.

Note 3: Nitrogen deposition at receptor E1e (pioneer, low-mid saltmarshes).

NOx (annual)

At the Humber Estuary the PEC is over the 70% threshold, requiring further assessment (refer to our assessment below). The Applicant noted that the background concentrations already include the existing contribution from the Installation, and therefore it is considered that the actual PECs will be below these values.

For all other receptors, except the worst-case Humber Estuary and North Killingholme Haven Pits, the predicted annual average NOx concentrations are below 1% of the ES and therefore are considered insignificant.

NOx (daily mean)

At the Humber Estuary, the PC is 16% of the EQS, with the PEC at 56% of the EQS, so the Applicant concludes that an exceedance of the EQS is very unlikely to occur as a result of the existing emissions from the Installation.

The daily mean NOx concentrations represent approximately 10% of the EQS at the majority of receptors, and therefore existing impacts are largely insignificant.

SO_2

For all receptors the predicted annual average SO_2 concentrations are below 1% of the EQS and therefore are considered insignificant.

Nitrogen and acid deposition

For all receptors the predicted deposition loads are below 1% of the EQS and therefore are considered insignificant.

5.4.2b Future - The modelling predicted maximum pollutant concentrations at the Humber Estuary receptor

Future – maximum at the Humber Estuary							
Pollutant	EQS/EAL (µg/m^3)	Back-ground (µg/m^3)	PC (µg/m^3)	PC as % of EQS/ EAL	PEC (µg/m^3)	PEC as % EQS/ EAL	Change in PC over baseline %
Direct Impacts [Note 1]							
NO_x Annual mean	30	20	2.51	8.4	22.51	75	+4.5
NO_x Daily mean	75	30	17.8	23.7	47.8	63.7	+7.7
SO_2 Annual mean	20	-	0.18	0.9	-	-	+0.4
NH_3 Annual mean	3	1.7	0.1	3.3	1.8	60	+3.3
Deposition Impacts [Note 1]							
Nitrogen deposition (kg N/ha/yr) [Note 3] Annual mean	20	17	0.88	4.4	17.88	89.4	+3.9
Acid deposition (Keq/ha/yr) [Note 2] Annual mean	Min CL Min N – 0.499 Min CL Max N – 0.792	-	N: 0.0053 S: 0.0022	0.7	-	-	+0.2

Future – maximum at the Humber Estuary							
Pollutant	EQS/EAL (µg/m³)	Back-ground (µg/m³)	PC (µg/m³)	PC as % of EQS/ EAL	PEC (µg/m³)	PEC as % EQS/ EAL	Change in PC over baseline %
	Min CL Max S – 0.150						

Note 1: Direct impact units are µg/m³ and deposition impact units are kg N/ha/yr or Keq/ha/yr.

Note 2: For acidification, there is no critical load assigned to the Humber Estuary in APIS. We have included the most impacted receptor with a critical load, which is Wrawby Moor SSSI.

Note 3: Nitrogen deposition at receptor E1e (pioneer, low-mid saltmarshes).

NOx (annual)

At the Humber Estuary the PEC is over the 70% threshold requiring further assessment (refer to our assessment below). As above, the Applicant notes that the background concentration used in the assessment will include the contribution from the existing Installation sources, and therefore there is some double counting of the Installation's future impacts in the PEC value.

In addition, this level of impact only occurs at the worst-case location of the Humber Estuary, and over the majority of the Humber Estuary site the predicted PCs will be lower. It is therefore considered that the effects over the site as a whole, will not be significant.

All other receptors experience lower NOx impacts, that either show an increase of less than 1% of the EQS, or the PECs remain well below the second screening stage threshold of 70%, and therefore the impacts are considered not to be significant.

The change in PC over the baseline assessment is 4.5%.

NOx (daily mean)

At the Humber Estuary, the PC is 23.7% of the EQS, with the PEC at 63.7% of the ES, so they conclude that an exceedance of the ES is very unlikely to occur as a result of the emissions from the proposed Installation.

The change in PC over the baseline assessment is 7.7%.

SO_2

For all receptors the predicted annual average SO_2 concentrations are below 1% of the EQS and therefore are considered insignificant.

The change in PC over the baseline assessment is 0.4%.

NH_3

At the Humber Estuary, the PC is 3.3% of the EQS, with the PEC at 60% of the EQS, so they conclude that an exceedance of the EQS is very unlikely to occur as a result of the emissions from the proposed Installation.

The change in PC over the baseline assessment is 3.3%.

Nitrogen deposition

At the Humber Estuary the PC is 4.4% of the EQS, with the PEC 89.4% of the EQS.

At all other receptors, with the exception of E2, the PCs are below the 1% insignificance threshold.

The Applicant confirmed that the Natural England condition assessment for the North Killingholme Haven Pits SSSI Unit 1 (which is the location of the Humber Estuary wetland and reedbed receptor) states that the habitat is in favourable condition as it is meeting its targets for habitats supporting qualifying species of waterbirds, and this is set within the context of the existing high background nitrogen deposition. Reedbed habitats are also reasonably assumed to be not particularly susceptible to damage from the small increases in nitrogen uptake predicted in the assessment. The report concluded that there will be no changes in the extent or distribution of reedbed habitats supporting qualifying species of waterbirds that are functionally linked to the Humber Estuary SPA / Ramsar, such that the conservation objectives for the SPA/ Ramsar would be compromised.

The small nitrogen deposition contribution resulting from the operational emissions to air of the PCC plants therefore are not reasonably expected to result in any changes to the extent or distribution of this habitat within the Humber Estuary such that the conservation objectives would be compromised.

The change in PC over the baseline assessment is 3.9%.

Acid deposition

For all receptors the predicted deposition loads are below 1% of the EQS, therefore demonstrating insignificance.

The change in PC over the baseline assessment is 0.2%.

5.4.2c Environment Agency assessment

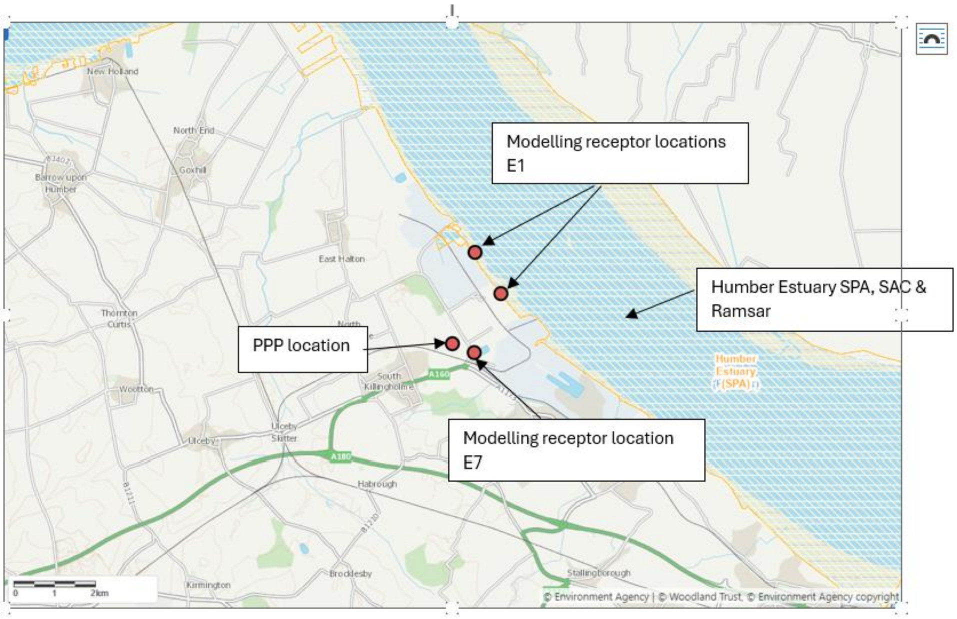
Habitats Regulation Assessment (HRA) - (Humber Estuary SAC, SPA, Ramsar)

As required under the Habitats Regulations, we completed a HRA, which included a stage 1 and stage 2 HRA (appropriate assessment – in combination). This assessment is available to view on our public register and is summarised below.

The stage 1 HRA identified that PCs may have a likely significant effect on the integrity of the habitat sites. We carried out a stage 2 HRA (appropriate assessment) of the impacts to determine if they would have an adverse effect on the habitat sites, see below.

- Rosper Road Pools LWS (E7)

Our HRA also considered Rosper Road Pools LWS (E7), see map below. Whilst this site is not part of the Humber Estuary designations (E1a to E1f), it is functionally linked to the estuary as it provides breeding grounds for avocet, a notified feature of the Humber Estuary SPA. Potential impacts on the avocet can also give us a good indication of potential impacts on other qualifying bird species in the vicinity and therefore impacts at this protected site can be used as a worst-case scenario. As such, this location is included in the parts of the assessment that relate to the SPA designation.



- Acid deposition

Whilst acid deposition will result from the facility and has been included in the Applicant's assessment, the notified features and/or habitats present at the receptor locations are not considered sensitive to impacts from it. We therefore conclude that there would not be any effect at all from acidification.

- SO_2

The modelling showed PCs to screen out as insignificant at <1% of the EQS so no further investigation was necessary.

- NH_3

The PC was above the 1% insignificance threshold, with the PEC at 60% of the EQS. We therefore concluded there will be no likely significant effect alone.

- NOx

The PCs were above the short and long-term 10 and 1% insignificance thresholds, with PECs of 63.7% of the EQS (short-term) and 75% of the EQS (long-term). For short-term emissions this is sufficiently low to conclude no likely significant effect. For long-term emissions we carried out an appropriate assessment.

For long-term NOx emissions we consider that with a PEC of 75% of the EQS, this leaves sufficient headroom to be confident that there would be no adverse impact on the designated site. The PCs used for modelling represent a worse-case scenario; in reality operating conditions are likely to be such that emissions would be lower than presented and it is unlikely that the PCs would lead to a compromising of the site's conservation objectives.

It is also noted that the proposal forms part of the Humber Zero Project, and that implementation of the PCC will have a significant positive impact on overall pollution levels in the Humber region.

It is therefore concluded that the NOx PCs from this proposal will have no likely adverse impact on the habitats sites.

We also concluded that there would be no adverse effect on the integrity of the sites in-combination with other applications.

- Nitrogen deposition

Information available on our systems and the Priority Habitat Inventory (PHI) show that of the habitats modelled, only saltmarsh is present at or near the receptor locations. The nitrogen deposition PC for this habitat is above the significance threshold with a PEC of 89.4% of the EQS, indicating a likely significant effect. We carried out an appropriate assessment to determine if this is likely to lead to an adverse impact.

An exceedance of the EQS was identified for an area above the mean high-water mark, this was almost entirely due to the background loading, with the PC at 1.75% of the EQS and the PEC at 174% of the EQS.

The actual PCs are relatively small in comparison and the area of upper saltmarsh present at this location represents a very small fraction of overall saltmarsh habitat in the estuary. There is no evidence that the current background load is having an adverse impact on the saltmarsh.

The PCs used for modelling represent a worst-case scenario; in reality operating conditions are likely to be such that emissions would be lower than presented and it is unlikely that the PCs would lead to a compromising of the site's conservation objectives.

It is also noted that the Application forms part of the Humber Zero Project, and that implementation of the PCC will have a significant positive impact on overall pollution levels in the Humber region.

We concluded that there will be no adverse effect on the integrity of the sites in combination and that this conclusion is not dependent any mitigation measures or conditions.

We sent the HRA to Natural England for consultation and recorded their response in Annex 2 of this document. They had no objections to the proposal.

Countryside and Rights of Way Act (CRoW) – (Humber Estuary SSSI)

We reviewed the Applicant's SSSI assessment and agree with the conclusions, that there would be no likely damage caused to the features of the SSSI as a result of this proposal.

- SO_2

The modelling showed PCs to screen out as insignificant at <1% of the EQS so no further investigation was necessary.

- NH_3

The PC at location E1 was above the 1% insignificance threshold, with the PEC at 60% of the EQS. We therefore concluded it was unlikely to damage the SSSI as the PEC is below the EQS.

- NOx

The PCs were above the short and long-term 10% and 1% insignificance thresholds at the saltmarsh, with PECs of 63.7% of the EQS (short-term) and 75% of the EQS (long-term). As this is well below the EQS it can be concluded that it is unlikely to lead to damage to the SSSI.

- Nitrogen deposition

Nutrient nitrogen deposition was predicted to be above the 1% insignificance threshold of the critical load for saltmarsh (E1e). The subsequent PEC was 89.4% of the EQS. We therefore concluded that it was unlikely to damage the features or the habitats on which they depend as the PEC is below the EQS.

As required under the CRoW, we completed an Appendix 4 Notice which details our assessment and conclusions. Based on our conclusions, we were not required to send this to Natural England for consultation; however it is available to view on our public register.

5.4.3 Assessment of local nature sites

Conservation sites are protected in law by legislation which provides the highest level of protection for SACs and SPAs, and also for protection of protection for SSSIs. The Environment Act 1995 provides more generalised protection for flora and fauna rather than for specifically named conservation designations. It is under the Environment Act 1995 that we assess other sites (such as ancient woodlands, local wildlife sites and national and local nature reserves) which prevents us from permitting something that will result in significant pollution; and which offers levels of protection proportionate with other European and national legislation. However, it should not be assumed that because levels of protection are less stringent for these other sites, that they are not of considerable importance. Local sites link and support EU and national nature conservation sites together and hence help to maintain the UK's biodiversity resilience.

For SACs, SPAs, Ramsars and SSSIs we consider the PC and the background levels in making an assessment of impact. In assessing the local nature sites under the Environment Act 1995 we look at the impact from the Installation alone to determine whether it would cause significant pollution. This is a proportionate approach, in line with the levels of protection offered by the conservation legislation to protect these other sites (which are generally more numerous than Natura 2000 or SSSIs) whilst ensuring that we do not restrict development.

Critical levels and loads are set to protect the most vulnerable habitat types. Thresholds change in accordance with the levels of protection afforded by the legislation. Therefore, the thresholds for SAC SPA and SSSI features are more stringent than those for local nature sites.

Therefore, we would generally conclude that the Installation is not causing significant pollution at these other sites if the PC is less than the relevant critical level or critical load, provided that the Applicant is using BAT to control emissions.

The maximum impact from the future scenario is from the daily mean NOx which is only 20% of the critical level at Eastfield Road Pit.

The PC is less than the relevant critical levels and loads at all of these other sites, so we conclude that the Installation will not cause significant pollution. The Applicant is required to prevent, minimise and control emissions using BAT, this is considered further in Section 6 of this document.

5.5 Impact of abnormal venting of carbon dioxide (CO_2)

The release of highly concentrated CO_2 under pressure from the PCC plants has the potential to cause harm to human health. It is recognised that for installations of the type proposed that venting to atmosphere of concentrated CO_2 may be required during operation of the Installation. For this reason, the Applicant was required to provide an assessment of the risk of the vented concentrated CO_2 causing harm to health at nearby sensitive receptors.

The Applicant provided an assessment which presented a number of vent release scenarios under which CO_2 may be vented to atmosphere. They used DNV PHAST version 8.7 to predict impacts on nearby receptors.

The impacts were compared to concentrations of interest, based on HSE Workplace Exposure Limit guidance and the Energy Institute Draft guidelines for “Hazard Analysis for Onshore and Offshore Carbon Capture Installations and Pipelines”.

The Applicant concluded that concentrations of CO_2 are likely to be below the levels at which the onset of symptoms and effects are reported, and the modelling indicates that even the lowest long-term exposure limit (LTEL) of 0.5% (5,000 ppm) does not reach the ground for any of the cases identified or reach any of the identified human health receptors. Overall, the dispersion modelling indicates that the gas plumes from planned or unplanned events will be of very limited extent, and at a height that will not cause any impact.

Environment Agency assessment

We have audited the Applicant's assessment, and we agree with their conclusions, provided that CO_2 venting is minimised, according to the techniques described and is reasonably within the scope and conditions modelled.

The Applicant's conclusions can be used for determination with the following caveats:

- a minimum height of 40 m;
- a maximum CO_2 release rate of 86 kg/s with vent and orifice diameters conducive to mass rates provided in the Applicant's report; and
- there are no structures that would interfere with the CO_2 plume.

Since submission of the Application, we have changed our approach to the assessment of venting of CO_2 from carbon capture activities and no longer request or audit CO_2 venting models.

Consistent with our changed approach, we have included a pre-operational condition in the Permit. This requires the Operator to provide a report that validates the outcomes of the CO_2 venting emissions to air risk assessment presented in the Application. It requires submission of a vent management plan and details of the operating techniques to be used to minimise the risks from the venting of CO_2.

5.6 Other emissions to the environment

5.6.1 Emissions to water

Existing drainage

The existing Installation drainage system has three holding ponds; M1, M2 and M3.

- Holding pond M1 collects process water from the existing Installation, mainly blow-down from the cooling water circuit, which is held and tested, and if acceptable is pumped to M2.
- Holding pond M2 collects surface water drainage from the existing Installation and where there is potential for oil contamination to occur, the drainage system goes through an oil/water interceptor.
- Holding Pond M3 collects the condensate from the steam cycle from the Installation, the water is tested and discharged to M2;
- Waters from holding ponds M1 and M3 are discharged to holding pond M2 prior to discharge;
- From holding pond M2, the combined wastewaters are discharged to the existing South Killingholme Drain outfall at emission point W1 (NGR 517000, 417190).

The existing Environmental Permit includes emission limits and monitoring requirements for Emission Point W1, including a maximum daily flow rate and limits on pH, temperature, oil, ammoniacal nitrogen, total suspended solids, chemical oxygen demand (COD) and dissolved oxygen.

Proposed PCC plants drainage

Refer to the drainage plan below, copied from the Application Main Supporting document, dated December 2023.

The PCC plant areas will result in:

- clean surface water run-off;
- potentially contaminated surface water (PCSW) run-off; and
- process effluents, closed drainage for wastewater potentially contaminated with amines.

The drainage systems associated with the PCC plant areas will have a single level of primary treatment available via a class 2 oil/water separator, designed to achieve 100 mg/l of oil, and two potential routes for discharge:

- either via a new balancing pond M4 and high efficiency class 1 oil/water separator, designed to achieve 5 mg/l of oil, draining to a new site outfall at emission point W2 (NGR 517130, 417000) draining to the South Killingholme Drain; or
- contaminated process effluents which will go to a drain drum which will be emptied when required via vacuum truck for off-site disposal via a licensed waste contractor.

The Applicant confirmed that the wastewaters discharged via emission point W2 will be uncontaminated. Controls will be in place in the form of valves within the drainage systems to ensure contaminated wastewater collected in bunds is not released into the surface water drainage system without prior testing to ensure that they are not contaminated.

Storm water drain (uncontaminated surface water run-off)

During normal operation, the direct contact cooler (DCC) blow-down water will be returned to the raw water tank for treatment in the demineralisation (demin) plant for reuse on site. There will also be provision for this stream to be diverted to the M4 holding pond and discharged through W2 to South Killingholme drain, in the unlikely event that the raw water tank is full. The Applicant stated that such an occurrence would be very rare and therefore would represent an abnormal operation. It is anticipated that the duration of such a release would be limited to two hours in most cases.

The DCC blow-down water will be 99.99% water, hence enabling its normal routing to the demin plant for reuse on site, however there is potential for trace sodium sulphate salts to be present due to the addition of caustic to the DCC to remove SO_2 from the auxiliary boiler flue gas when firing on ROG.

As such, it is not anticipated that there will be any additional pollutant species released to controlled waters as a result of the operation of the PCC plants.

We have limited this operation in table S3.2 of the Permit and included process monitoring in table S3.4 to record the number and duration of events.

PCSW

On a precautionary basis, uncontaminated surface water will be routed to the PCSW drainage and the Class 2 oil/water separator prior to the new surface water holding pond (M4) for discharge at W2. The Applicant has confirmed that only uncontaminated surface runoff will discharge at W2.

Contaminated waters may be transferred by tanker, or transferred to the existing on-site treatment facilities, provided contaminant levels are permissible for treatment, and be discharged from W1 in line with the existing emission limits. If not, they will be disposed of off-site via a licensed third-party waste contractor.

PCC plants process waters (closed drainage)

Process drains, including routine draining of equipment and pipework for maintenance operations will, as far as practical, allow for the retention of drained fluids so that these can be returned to the appropriate system for reuse.

Equipment that does not contain amines will have liquid levels reduced as far as practical before being drained to a drain drum. Any fluids collected in the drain drum will be tested and be removed from site by tanker if they are contaminated, or if they are uncontaminated, will discharge to the PCSW drainage system and the class 2 oil/water separator prior to discharge to the holding point M4 for release at emission point W2. The Applicant confirmed that PCSW is effluent that may contain hydrocarbons and not amines.

Drainage for amine contaminated wastewater will be separate to the other drainage systems at the PCC plants to prevent it from entering the surface water drainage system. Amine contaminated wastewater will drain to a sump tank where it will be recovered for reuse in the amine process or tankered for off-site for treatment/disposal. It is therefore not considered to pose a contamination risk to surface water or groundwater receptors. On this basis a risk assessment was not carried out.

Amine drain

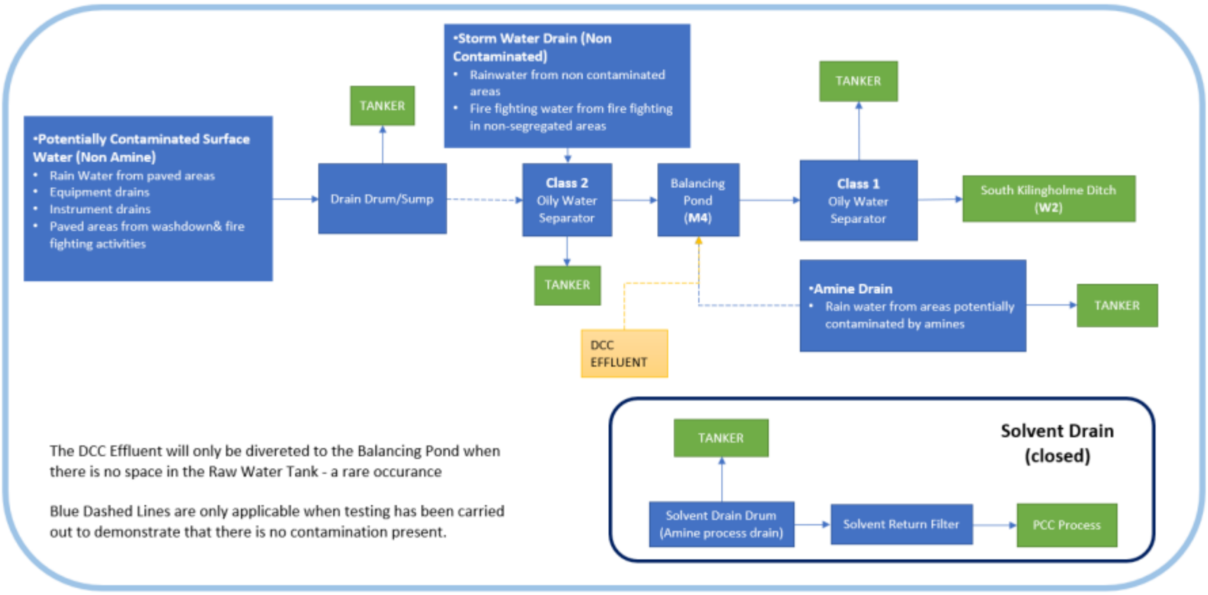
Effluent from the amine drain will be tested, with contaminated effluent transferred for off-site disposal by tanker. Uncontaminated waters will be routed to the M4 holding tank.

We have specified monitoring in table S3.4 of the Pemit requiring specific testing for amines to confirm that they are below the limit of detection prior to discharge to the M4 holding tank.

As an additional control we have also included an improvement condition for monitoring of amines in emissions to water from the PCC plants at emission point W2.

We are satisfied that the necessary controls will be in place to control emissions to water. The effluent release to the South Killingholme drain has not changed and therefore no Habitats Directive assessment is needed for water quality.

Figure 6 – Drainage Flow Diagram for the PCC Plant Area



5.6.2 Fugitive emissions

The IED specifies that plants must be able to demonstrate that the plant is designed in such a way as to prevent the unauthorised and accidental release of polluting substances into soil, surface water and groundwater. In addition, storage requirements for waste and for contaminated water of Article 46(5) must be arranged.

The Applicant has proposed a number of key measures to control fugitive emissions, refer to section 3.4 of this document for pollution prevention measures.

We have reviewed the techniques proposed by the Applicant and compared these with the relevant guidance notes and we consider them to represent appropriate techniques for the facility.

Solvent storage tanks

In their second response to our Schedule 5 Notice for further information dated 16/07/2024 the following additional information was provided:

The CANSOLV DC-103 tanks are provided with overflow lines to the bund. The vapour pressure of CANSOLV DC-103 is <0.13 hectopascal (hPa) (or 0.013 kPa) at 20°C.

The vapour pressure of CANSOLV DC-103 is therefore only just over 0.01 kPa, which is used for the definition of a Volatile Organic Compound (VOC) in the Industrial Emissions Directive (IED). It is therefore considered that the provision of overflow lines to the bunds of these tanks would not contribute to any significant fugitive emissions.

The vapour pressure of CANSOLV DC-103 is therefore much lower than that of MEA (0.05 kPa at 20°C).

As stated above, the vapour pressure of CANSOLV DC-103 is <0.013 kPa at 20°C, and not <0.13 kPa, as stated in the additional notes we included in our Schedule 5 question. The Main Supporting Document had an error in one reference to the CANSOLV DC-103 vapour pressure, leading to this misunderstanding.

The technology provider also confirmed that CANSOLV DC-103 does not need to be stored under nitrogen to prevent degradation from atmospheric oxygen.

Venting calculations were conducted in accordance with the methodology outlined within US Environmental Protection Agency Document - AP42, Fifth Edition, Volume I Chapter 7: Liquid Storage Tanks, for a range of venting options and mitigation measures.

Calculations for a 'base case' with no proposed emission controls, referred to as Emission Control Measures (ECM) in the Emissions from Storage BRef show the total atmospheric solvent losses to be 0.13 kg/year.

Although this may be considered acceptably low, an assessment was conducted to appraise the benefits of the following ECMs:

- base case – insulated atmospheric storage with no painted finished, with heater (@°30C);
- storage in white/milled finish tanks;
- low pressure nitrogen blanket; and
- high pressure nitrogen blanket.

Although reductions in venting losses were achieved with all ECMs, given the very low losses of 0.13 kg/year associated with the base case, it was considered that the significant additional capital cost to provide tanker vapour balancing and/or nitrogen blanketing was not justified.

In addition, and as stated above, it has been confirmed that, unlike MEA, CANSOLV DC-103 does not degrade/decompose when exposed to atmospheric oxygen and therefore does not need to be stored under nitrogen to prevent degradation.

The tanks and associated secondary containment will be designed to remove as far as reasonably practical any groundwater contamination pathway for the solvent in the unlikely event of a leak or tank failure. On this basis the tank will be designed in accordance with API 650 standard and the secondary concrete, and any required lining or coatings, will be designed in accordance with EN 1992 Eurocode 2: Design of concrete structures and CIRIA; Containment systems for the prevention of pollution (C736F) and be compatible with CANSOLV DC-103. This will be supported by appropriate process monitoring, such as rate of loss and sump level indication. These will be supported by further manual checks as part of normal operational and maintenance routines. Suitable process control system will be put in place to monitor the tanks such as rate of loss etc.

We have set a pre-operational condition requiring the final design of the solvent storage tanks to have white painted or milled finish as a minimum.

We are satisfied that the necessary controls will be in place, and we consider them to represent appropriate techniques for the facility.

5.6.3 Odour

Based upon the information in the Application we are satisfied that the appropriate measures will be in place to prevent or where that is not practicable to minimise odour and to prevent pollution from odour.

The Applicant has stated that the proposed amine solvent will have a low vapour pressure at ambient temperatures and therefore consider the risk of amine odour to be low. They have stated that a leak detection and repair (LDAR) system will be implemented at the proposed Installation.

The Applicant considers that due its low volatility there is minimal potential for odour issues to arise from the solvent. The odour of the Cansolv DC-103 is described as sweet, and therefore is not expected to be as unpleasant as the typical amine smell. A leak detection and repair (LDAR) system will be implemented at the proposed Installation.

The permit includes condition 3.3.2 which requires the Operator to submit an odour management plan for approval if notified by the Environment Agency that the activities are giving rise to pollution outside the site due to odour.

We are satisfied that the necessary controls will be in place to control odour.

5.6.4 Noise and vibration

The Application included a noise impact assessment (NIA) dated November 2023. The noise modelling used the software package SoundPLAN following the procedure set out in BS 4142:2014 +A1: 2019 ‘Methods for rating and assessing industrial and commercial sound’ (BS 4142). The NIA was based on preliminary noise data available at this stage of the design of the proposed PCC plants.

Background sound levels

Background sound levels and operational sound levels from the existing site were provided from a variety of surveys and studies, which included:

- Bureau Veritas (2010) 3952671/2 Rev 2 Immingham Environmental Survey. This document states the previously agreed background noise level was 58.4 dB on Page 4 of the document.
- CHP Noise Development Plan. This document was used to determine the background sound level prior to VPI being operation. (52 dB LA90,T as stated on Page 57 of the document).
- AECOM (2022) environmental Statement Chapter 7 Noise & Vibration and Appendix 7A Sound Survey Information. Baseline survey information reviewed and concluded there was very little variation in the ambient sound levels during the day and night-time periods.
- Bureau Veritas (2023) 18917525/1 Rev 0 Immingham CHP Environmental Noise Survey June 2023. This document was used to determine the existing specific noise from VPI.

Operational scenarios

The NIA considered the following scenarios:

- Scenario 1: All proposed plant operating - worst case scenario
- Scenario 2: All proposed plant operating apart from the air coolers in the northern PCC plant train and associated plant - a more typical operating scenario; and
- Scenario 3: All proposed plant operating apart from the air coolers in the southern PCC plant train and associated plant - a more typical operating scenario

As the detailed design of the proposed PCC plants is not yet finalised, for each potential source of noise the assessment provided generic noise attenuation values the Operator expects to achieve once the design is finalised, and a proposed hierarchy of noise control measures for the application of BAT. This is based on generic commitments for noise mitigation, such as eliminating and/or reducing noise sources and implementing engineered solutions such as acoustic enclosures and barriers.

Sound climate and sources

The Applicant confirmed that the Installation is located in a heavily industrialised area. The existing sound climate is characterised by noise from the existing Installation, and similar adjacent uses, in particular the Phillips 66 Humber Refinery to the west and Lindsey Oil Refinery to the north. Additional industrial and commercial operations in the area include DFDS, DVS, Scangrit, Killingholme Power Station and the Port of Immingham, which generate noise from vehicle movements and general industrial activity.

The dominant sound sources within the site vary depending on the proximity to the receiver location. In general pumps, air fin coolers and compressors are the plant types making the greatest contributions to the existing sound climate.

Noise sensitive receptors (NSRS)

The Applicant confirmed that the worst affected NSRs to the site are as follows:

- NSR1: Staple Road, 1.5 km south-west of the site
- NSR2: Clarks Road, 1.9 km west of the site
- NSR3: Church Lane, 1.9 km north-west of the site
- NSR4: Hazel Dene, 340 m east of the site

Applicant’s conclusions

Existing operations: low impact

Proposed variation (PCC plants): below adverse impact (with mitigation)

Existing site + variation (future operation): adverse impact (before context considerations), low impact (after context considerations)

Based on the worst-case scenario 1, the rating level would be less than 5 dB above the defined background sound levels (i.e. below the level at which there is an indication that adverse impacts are likely). The resulting significance of impact in accordance with BS 4142 has been determined as either “low impact” or up to “adverse impact” (before context considerations).

The context discussion considers the predicted specific sound levels in relation to the relevant World Health Organisation (WHO) Guidance indoors and outdoors and the more recent Night Noise Guidelines. It is concluded that the PCC plants are predicted to meet with the WHO guideline values externally.

Therefore, overall, considering the BS 4142 assessment outcomes in the context of the existing sound environment, noise impacts from operation of the PCC plants in combination with the existing CHP plant on the nearest NSR4 (a single residential property) would have a low impact.

However, at the detailed design stage, opportunities to reduce the predicted specific sound levels further will be explored and VPI will continue to follow appropriate BAT as part of the environmental management plan and undertake annual environmental noise monitoring.

Environment Agency assessment

Audit conclusions

Existing operations: adverse impact

Proposed variation (PCC plants): adverse impact (with mitigation)

Existing operations + variation (future operation): significant adverse impact

Background sound levels

The Applicant's NIA referenced background sound data from several studies made by AECOM and others. We consider that the background sound levels are likely to be lower than the Applicant has stated, which increases the risk of noise impacts from the proposed variation.

The background sound levels measured by AECOM in 2022 at NSR4 varied over the survey period, and we have identified a potential for lower background sound levels than the 52dB LA90 for day and night periods used in the NIA, under certain wind direction conditions (north-east direction). This increases the noise risk from the proposed variation during some periods.

We further validated the potential for lower background sound levels at NSR4 by analysing the data presented in the Bureau Veritas study from 2023 submitted with the Application, which clearly shows background sound levels which are lower than the values assumed.

On this basis, the revised NIA (based on the detailed design) to be submitted via a pre-operational condition (see below), will need to consider the possibility of lower background sound levels at NSR4.

NSRs

We agree that the Applicant has identified the worst affected NSRs.

The NIA has considered the impacts at NSR4 only, as this receptor is much closer than the other receptors and therefore most likely to be subject to noise pollution from the existing site and the proposed variation. We agree with this approach.

Impact from existing operations

The NIA presented specific sound levels from existing operations at the site, based on data which was measured and modelled by other consultants. The NIA identifies low impacts from existing operations at the nearest NSR, Hazel Dene. We consider that the operational sound level from the existing site is representative at this NSR but disagree with the impacts from existing operations.

Acoustic feature corrections (AFC)
The revised NIA (based on the detailed design) to be submitted via a pre-operational condition (see below), will need to consider the applicability of AFCs.

Mitigation measures
Without mitigation measures, the Applicant's noise modelling outputs result in an adverse impact from the proposed variation, based on the assumptions stated in the NIA regarding background sound levels. Our audit concludes a significant adverse impact due to the lower background sound levels we identified. Mitigation measures are therefore required to reduce the impact from the proposed variation.

With outline mitigation proposals in place, the NIA considers that the impact from the proposed variation will be below adverse, which is reduced to low after context is considered.

In addition to the lower background sound levels, we identified minor discrepancies in the Applicant's modelling files, which result in marginally higher specific sound levels than those provided. We therefore consider that an adverse impact will occur from the proposed variation, with the outline mitigation in place.

In line with the aims of the Noise Policy Statement for England (Noise policy statement for England - GOV.UK) and The Environment Agency's guidance (Noise and vibration management: environmental permits - GOV.UK) and standard permit condition for noise, adverse impacts are permissible provided that the site is working to BAT (Best available techniques: environmental permits - GOV.UK and BAT reference documents | EU-BRITE) . The Applicant has already proposed techniques that are considered to be BAT in accordance with the emerging techniques guidance for carbon capture, so the impacts identified by us are acceptable subject to a full assessment of the techniques against the emerging techniques guidance for carbon capture and a revised NIA being submitted and approved by us following detailed design. This is addressed via a pre-operational condition, see below.

Measures that are considered to be BAT in accordance with the emerging techniques guidance for carbon capture should focus on mitigating the dominant sound sources as far as is practicable, i.e. those set out in table 7.1 of the NIA.

The revised NIA (based on the detailed design) to be submitted via a pre-operational condition (see below), will need to include detailed performance specifications for all proposed mitigation options in octave frequency bands. Specifications will need to be evidenced by manufacturer's data where available.

Noise Management Plan (NMP)

We compared the mitigation proposals shown in the Applicant's NMP (Revision 1.0, dated 08/12/2023) to those detailed in table 7.1. 'Attenuation Required (dB from individual plant items)' of the NIA. These are set out in the NMP in 'Table 3: Activities and procedures which will be in place to achieve appropriate measures / best available techniques (BAT)', under section 6.6 Control measures and process monitoring, 6.6.1 Appropriate measures and Best Available Techniques (BAT).

We confirm that the mitigation proposals in the NMP are consistent with those in the NIA.

We have reviewed the NMP in accordance with our guidance on noise assessment and control. We consider it to be satisfactory and we approve this plan, however, since the design is preliminary, the NMP is required to be updated according to the outcomes and the detailed performance specifications for all proposed mitigations and submitted to us for approval in accordance with a pre-operational condition.

The Applicant should keep the plans under constant review and revise them annually or if necessary, sooner if there have been complaints arising from operations on site or if circumstances change. This is in accordance with our guidance 'Control and monitor emissions for your environmental permit'.

The plan has been incorporated into the operating techniques S1.2; however it is linked to the pre-operational condition requiring an updated NIA following detailed design, so may be subject to change. We have also deleted Permit condition 3.4.2 which is not required where a NMP has been submitted and approved.

Overall conclusions

We conclude that the proposed changes will increase the noise impacts associated with the existing site operations. This is based on outline design proposals and mitigation measures being accounted for in the predicted impacts. The conclusions of the NIA and our audit do not prevent this variation being issued for the proposed changes; however, the site should be working to BAT in accordance with the emerging techniques guidance for carbon capture. Our assessment of BAT is set out in section 6 of this document.

A further NIA and noise modelling will be required following the detailed design stage. We have included a pre-operational condition to address this. We will audit the revised NIA and associated noise modelling. At this point we can review the noise impacts from the Operator's final plant design, and we will not approve the proposals unless we are satisfied that all of the above points have been addressed.

Based upon the information in the Application we are satisfied that the appropriate measures will be in place to prevent or where that is not practicable to minimise noise and vibration and to prevent pollution from noise and vibration outside the site as long as the relevant pre-operational condition we have specified is completed satisfactorily.

6. Application of Best Available Techniques (BAT)

6.1 Scope of consideration

In this section, we explain how we have determined whether the Applicant's proposals are the Best Available Techniques (BAT) for this Installation.

- we address the carbon capture plant, including emission control measures;
- we address hydrogen production by electrolysis of water; and
- we consider the cooling system proposed.

The Applicant confirmed that the combustion activities carried out at the Installation will remain compliant with the IED, LCP BAT Reference document (BRef) and the associated LCP BAT Conclusions (BATc). As this is an existing activity, additional assessment of compliance with the combustion activity against the LCP BAT requirements has not been undertaken.

They also confirmed that there would be no change to the existing operation of the two gas turbines (GT1 & GT2) and the two auxiliary boilers (AB1 & AB2) from that described in the original Permit Application for the Installation as a result of the PCC plants, and, therefore, no consideration of the upstream combustion process was included with this Application.

We agree with this approach.

6.1.1 Carbon capture plants

This Application is to retrofit two trains of Post-Combustion Carbon Capture (PCC) plants treating the flue gas emitted from the Installation's existing two gas turbines (GT1 & GT2) and the two auxiliary boilers (AB1 & AB2), removing CO_2 for subsequent compression and storage. Refer to process flow diagram below.

It falls under the following EPR Schedule 1 listed activity description:

Section 6.10 Part A(1)(a) - Capture of carbon dioxide streams from an installation for the purposes of geological storage.

The PCC plants will use an amine-based proprietary solvent (Shell Cansolv DC-103) to strip CO_2 from the flue gas within packed absorber columns, via a weak acid-base reaction.

The flue gas will be cooled by direct contact with recirculating water within the direct contact cooler (DCC). The recirculating water will be cooled against air in the DCC water cooler.

The CO_2-depleted flue gas will then pass through emissions abatement equipment (a water wash and mist eliminator) prior to its release to atmosphere. This will be via dedicated stacks on top of the PCC plants absorber towers at new emission points to air A6 (PCC plant 1) and A7 (PCC plant 2).

The main PCC stack emissions will comprise residual pollutants from the GTs and auxiliary boilers, including NOx, CO, SO_2, particulates and some residual CO_2. SO_2 and particulates are present due to the potential use of Refinery Off Gas (ROG), as a fuel in the auxiliary boilers and will only be present in trace amounts.

The PCC plants will be designed to optimise CO_2 capture and to achieve 95% capture rates during normal operation.

There may also be trace pollutants within the flue gas, including trace levels of amine from the solvent and amine break-down products from within the carbon capture process. These amine emissions will be monitored and minimised using a water wash section and mist eliminator at the top of the PCC plant absorbers prior to final release to air of the flue gas.

In addition to the main PCC plants emission points A6 and A7, there will be a CO_2 vent (emission point A8) on the CO_2 compression plant for use during start-up and shut-down, and in the event of abnormal operation.

The CO_2 will be removed from the CO_2-rich solvent in a CO_2 stripper (or regeneration column) by heat, using steam provided by the VPI CHP Power Plant, enabling the lean amine-solvent to be recycled back into the absorption process for reuse.

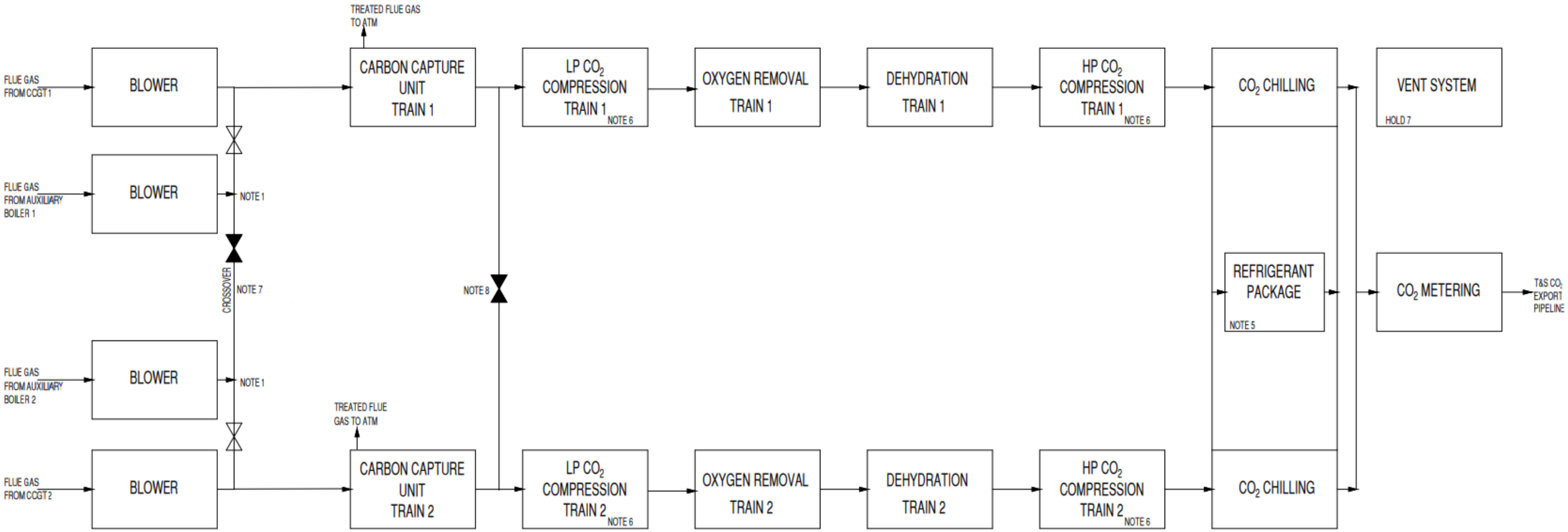
The CO_2 gas will undergo low-pressure (LP) compression, with dehydration and de-oxygenation also carried out. It will then undergo high-pressure (HP) compression on-site, to dense phase before being exported off-site to the third-party operator for transport to permanent underground storage.

Solvent impurities will be removed via a solvent thermal reclaiming process which will be carried out continuously within the PCC plant areas.

The assessment of the operating techniques proposed for the PCC plants against our guidance on emerging techniques (GET) is set out in Appendix D of the Application Main Supporting document, dated December 2023.

Further information on how the proposed operating techniques compare against BAT in accordance with the emerging techniques guidance for carbon capture was provided by the Applicant in response to the Schedule 5 Notice served on 16/07/2024 (responses received on 26/09/2024, 03/10/2024 and 07/11/2024). We have included the relevant Application documents and responses to the request for additional information in table S1.2 of the Permit, as operating techniques that the Operator will need to follow, according to condition 2.3.1 of the Permit.

The Applicant has addressed the relevant requirements set out in our guidance on emerging techniques (GET) at Post-combustion carbon dioxide capture: emerging techniques - GOV.UK (www.gov.uk). We have reviewed the Application against this, with the table below providing a record of decisions made in relation to each relevant requirement considered potentially applicable to the PCC plants.



PCC plant process flow diagram (reproduced from Application Main Supporting document, dated December 2023)

Meeting the requirements for Post-Combustion Carbon Capture

Ref	Requirement	Applicant's proposals	Our review of the Applicant's proposal meeting the requirements of our guidance Y/N/NA
2. Power Plant selection and integration with the PCC plant			
BAT for efficiency of fuel use in power and CHP plants with PCC.			
2.1	You must maximise the thermal energy efficiency of the power plant and of the supply of heat for the associated PCC plant. For natural gas power plants, lower heating value efficiencies of 60% or above without CO_2 capture are reported in the LCP BREF to be	The Applicant confirmed that opportunities for maximising thermal energy efficiency have been explored and integrated in the design of the PCC plants. For instance: • the air-cooled systems for the PCC plants are to include forced draft fans to minimise heat recirculation so as to reduce the overall cooling load. • the fan motors will also have variable drives which will ensure the number of fans in operation is proportional to the cooling load. • mechanical vapour recovery (MVR) to reduce the PCC steam demand. • additional measures for maximising energy efficiency of the CHP power plant when fitted with PCC will be investigated during detailed design. They also confirmed that the Installation will continue to operate in accordance with the conditions of the existing Permit and also applicable sector guidance, in particular to the LCP sector guidance. The combustion activities carried out at the Installation will remain compliant with the IED, LCP BAT Reference document (BRef) and the associated LCP BAT Conclusions (BATc). As this is an existing activity undertaken at the Installation, additional assessment of compliance of the combustion activity against the LCP BAT requirements has not been undertaken. We are satisfied that the proposal meets the requirements of our guidance on emerging techniques for thermal energy efficiency. Not applicable as the PCC plants are retrofits to existing GTs and auxiliary boilers.	Y

	achievable for large-scale new combined cycle gas turbine installations.	We agree these requirements are not applicable to retrofitting PCC to the existing GTs and auxiliary boilers.	
Dispatchable Operation.			
2.2	In line with the needs of a UK electricity system with a large amount of intermittent renewable generation, all thermal power plants, including those with CO_2 capture, are likely to be dispatchable. This means that the power plant operator can, within technical limits on rates of change in output and on minimum stable generation levels, operate the plant at any required output, up to its full load, at any time, and sustain this output indefinitely.	The Applicant confirmed that the Installation operates as a baseload plant, principally providing heat and power to the adjacent refineries. As such, dispatchable operation will be limited to ramping up and down in response to grid demand (i.e. flexible operation). We agree with the Applicant's conclusions that these requirements of our guidance are not applicable to their proposal.	NA
2. Supplying heat and power for PCC operation			
2.3	You will need to use low grade (for example 130°C) heat and electrical power to operate the PCC plant. You should work out the amounts needed based on factors that include the: • selected solvent • PCC plant configuration • CO_2 capture level • CO_2 delivery pressure You should supply this heat and electricity from the main power plant. Where not possible, this will need to be by fuel combustion in ancillary plants (with CO_2 capture) that are then also treated as a power plant system for performance calculations.	The Applicant confirmed that initial estimates have been developed for heat and power requirements. These have been documented in specific FEED deliverables, including heat and material balance, electrical load list and the equipment list. These estimates are based on the project specific solvent. We are satisfied that the proposal meets the requirements of our guidance on emerging techniques for supplying heat and power.	Y
	The ratio between heat supplied as steam (or otherwise) and electricity output lost will depend on the: • temperature at which you need to supply heat • steam condenser cooling water temperature You should consider using a back-pressure turbine if it is not possible to supply enough steam to the PCC plant by extracting steam from a condensing turbine. If the plant needs to supply heat for district heating, and extracting steam to supply the PCC plant will mean there is insufficient steam to do this, you should consider using heat pumps or other plant to reduce the amount of steam required to meet that heat demand.	The Applicant confirmed that the existing CHP is configured to produce HP steam for the adjacent refineries. Retrofitting the Immingham CHP Power Plant to produce LP steam was considered but discounted due to technical challenges with implementation. To generate LP steam, HP steam will be let down via a new steam turbine generator. The generator will produce additional power for export/on-site consumption whilst the LP steam will be used in the PCC plants. In addition, the mechanical vapour recovery (MVR) scheme will result in a reduction in total energy demand compared to a scheme without MVR. We are satisfied that the proposal meets the requirements of our guidance on emerging techniques for supplying heat and power.	
3. Purpose			
3.1.1	The purpose of the PCC plant is to maximise the capture of CO_2 emissions for secure geological storage.	The Applicant confirmed that the PCC plants have been designed to capture approximately 95% CO_2 in the flue gas treated. In their response to our Schedule 5 Notice for further information dated 16/07/2024, they confirmed that capture rate would be ≥	Y Subject to approval of the improvement condition

	You should aim to achieve a design CO_2 capture rate of at least 95%, during normal operations, although operationally this can vary, up or down.	95%. This is the basis of the design, and the process guarantee statement mass balances for all minimum, normal and maximum operating cases. Based on the information provided, we are therefore provisionally satisfied that the proposed plant meets the requirements of our guidance on emerging techniques for the overall CO_2 capture efficiency. However, as the carbon capture performance stated in the Application is a design parameter, and the actual operation of the plant 'as built' may diverge from its design specification when taking into account transient and abnormal operations, we have set an improvement condition requiring the Operator to assess and confirm whether the actual carbon capture performance of the operating plant is consistent with its design specification over an extended period of time (i.e. one year of operation). Should the actual capture performance fall short of the minimum capture performance of 95% stated in our guidance, the Operator shall carry out an analysis of the issues affecting the performance of the plant and propose remedial actions for our approval to improve the capture efficiency performance.	
3.1.2	You will need to deliver CO_2: • at local transport system pressures (gas phase such as 35 bar or dense phase such as 100 bar) • with levels of water, oxygen and other impurities as required for transport and storage such as that for the system operator National Grid (NGC/SP/PIP/25 Dec.2019)	The Applicant confirmed that the on-site conditioning system will remove oxygen and water from the CO_2 and compress to dense phase to meet the requirements of the T&S network. The quality of the CO_2 will be monitored for compliance with export specifications for the temperature, pressure, water content, oxygen content, hydrogen content, CO, hydrogen sulphide, SOx, NOx and amines. In addition to quality monitoring, fiscal flow metering will be provided for custody transfer of CO_2 sent to the T&S network. Onward transport of the captured CO_2 will be undertaken by a separate operator after the on-site CO_2 metering station. We are satisfied that the proposal meets the requirements of our guidance on emerging techniques for CO_2 delivery.	Y
3.1.3	The PCC plant must also have acceptable environmental risks through preventing or minimising emissions, or render them harmless. You must achieve environmental quality standards for air emissions from the PCC plant and their subsequent atmospheric degradation products (including, for example, nitrosamines and nitramines). You should confirm this using:	The Applicant confirmed that air dispersion modelling was carried out to demonstrate that environmental quality standards for air emissions from the PCC plants and their subsequent atmospheric degradation products will not be exceeded as a result of the PCC plants' operation. The Air Impact Assessment is provided in Appendix F of the application.	Y

	- atmospheric dispersion and reaction modelling tools - specific site parameters which will define plant-specific ELVs	Our assessment of this is provided in section 5 of this document. The Permit sets limits for relevant pollutants as detailed in section 7 of this document. We are satisfied that the proposal meets the requirements of our guidance on emerging techniques for environmental risks associated with emissions to air.	
3.1.4	Your PCC system design should aim to minimise the overall electricity output penalty on the power or CHP plants from all aspects of PCC plant operation, as much as possible. It should do this while meeting the CO2 capture requirements set out in this guidance.	The Applicant confirmed that the design has optimised power demand through the selection of efficient equipment, implementation of energy recovery scheme MVR and selection of an energy efficient capture technology. As explained above (ref. 2.3), we are satisfied that the proposal meets the requirements of our guidance on emerging techniques for energy efficiency.	Y

3.2. Solvent Selection			
3.2.1	While the process design for the PCC plant is likely to be generally similar for all solvents, the amine solvent you select will determine details of the design and performance. Solvent types and published performance figures are described in the BAT review. There is particular concern about impacts on the environment from nitrosamines and other potentially harmful compounds formed by reaction of the amines and their degradation products with nitrogen oxides (NOx) in the flue gases. Check the environmental standards for air emissions for the protective environmental assessment levels. You have a choice between: • solvents using primary amines that may require more heat for regeneration but will not readily form stable nitrosamines in the PCC plant, especially if a high level of reclaiming is used to remove degradation products • solvent formulations including secondary amines or other species that may have lower regeneration heat requirements may readily form nitrosamines with NOx in the flue gases in the PCC plant - for controls, see section 3.3 on features to control and minimise atmospheric and other emissions The project-specific potential for absorber stack emissions and consequent environmental impacts will depend on the selected solvent. You should assess your plant design and operation, plus local environmental factors, based on: • direct emissions of solvent components • formation of additional substances in the PCC system and emissions of those substances • formation of further additional substances in the atmosphere from emissions from the PCC system	The Applicant confirmed that the PCC plants will utilise the Cansolv DC-103 solvent, and the plants have been designed with the specific solvent and degradation characteristics in mind. The solvent regeneration and reclamation process will minimise solvent degradation, in order to minimise emissions and potential environmental impacts, as demonstrated in the Air Impact Assessment. This assessment has taken into account both the direct and indirect impacts of N-amines resulting from anticipated amine and N-amine releases. In their response to our Schedule 5 Notice for further information dated 16/07/2024 the following additional evidence was provided: Shell CANSOLV DC-103 was selected for its overall performance as well as the ability of the technology provider to demonstrate scale-up of the technology and ability to back-up performance data with project guarantees. They have significant operational experience of their technology and solvents, which have been commercially deployed since 2012 and data on pilot plant for similar flue gas types. This provided VPI with reassurance that the details provided on CANSOLV DC-103 are based on actual performance data rather than concept data or aspirational performance. According to the Application, proprietary solvents, such as CANSOLV DC-103 are considered to offer significant benefits over the mature single solvent option of MEA, due to their lower volatility leading to lower amine emissions and solvent degradation rates, improved capture rates and better energy efficiencies. According to the Application, the CANSOLV DC-103 solvent is considered to have very good thermal and oxidative stability compared to MEA, which degrades at lower temperatures and with oxygen. For example, MEA would need to be stored under a nitrogen blanket to prevent oxidative degradation, whereas this is not required for CANSOLV DC-103.	Y

		The Applicant recognised that the Environment Agency's Post-Combustion Guidance on Emerging Techniques states that solvent formulations including secondary amines or other species may have lower regeneration heat requirements and may readily form nitrosamines with NOx in the flue gases. However, it is considered that the reclamation process included in the PCC plants design will enable any nitrosamines generated to be removed at the rate of generation, thereby minimising potential emissions. This is demonstrated by the very low emission limit value proposed, total N-amines 0.0013 mg/Nm^3. According to the information provided in the Application, it is considered that the N-amines associated with the CANSOLV - DC103 solvent are significantly less mutagenic than the nitrosamine used to derive the Environmental Assessment Level currently applied to the assessment of impacts of generic nitrosamines. Further evidence to support this conclusion is detailed in the Wagner et al. (2014) report referenced in Appendix F (Air Impact Assessment, dated December 2023, received 21/02/2024) which details the testing of a number of nitrosamines for their mutagenicity, including one of those associated with the CANSOLV DC-103 solvent and found that it was not mutagenic. It is therefore considered that the significant benefits of the lower energy demand, higher stability and ease of reclamation, outweigh the potential generation of N-amines that are more stable than those generated by MEA, especially when considering that the N-amines that may be generated are considered to be significantly less mutagenic than NDMA. We are satisfied that the proposal meets the requirements of our guidance on emerging techniques for the selection of the carbon capture solvent.	
3.2.2	The potential for solvent reclaiming and other cleaning methods is also an important factor in solvent selection. You should make sure it is practicable to remove all non-solvent constituents from the solvent inventory as fast as they are added during operation, to avoid accumulation. You should also make sure that you: • recover a high fraction of the solvent in the feed to the reclaimer during reclaiming.	The Applicant confirmed that the PCC plants will include solvent filtration units which will take a slip stream of the solvent from the absorber for continual cleaning. Most of the filtered solvent is routed to the Lean Solvent Coolers for reuse in the Absorbers, however a further slip stream of this will go to the Thermal Reclaimer, which will also operate continuously. The aim of solvent filtration and reclaiming is to ensure that a high proportion of solvent can be reused in the process, without compromising either the CO$_2$ capture	Y

	- Minimise reclaimer wastes and that they can easily be disposed of.	rate or the potential for emissions of degradation products to occur. Until operation commences it is not possible to confirm how much solvent can be reclaimed, although based on operating experience from plants utilising the same solvent, it is anticipated that > 99% of solvent will be reclaimed. In maximising solvent reuse on site, reclaimer wastes will be minimised as far as possible. In their response to our Schedule 5 Notice for further information dated 16/07/2024 the following additional evidence was provided: Degraded solvent will be reclaimed in a Thermal Reclaimer unit. A stream from the lean amine is continuously fed into Thermal Reclaimer, which is composed of a rectification and a stripping section which operates at vacuum and has been proven to achieve very high separation of the CANSOLV DC-103 amines. They also confirm that the reclaiming process is the same as that used at Boundary Dam and Brother CISA commercial units. The Brother CISA plant operates on a gas boiler plant with the flue gas therefore having a similar composition to the flue gas from VPI. The reclaimer has maintained the solvent working composition since start-up in 2014. The Boundary Dam unit has also demonstrated its capacity to separate amine and degradation products over 10 years of operation, although due to the power station being coal-fired, degradation rates were much higher than the design and exceeded its processing capacity. Additional reclaiming capacity had to be added, operating on the same principle. Learning from this has been taken into account in the design for new projects by including sufficient spare capacity in the design for the reclaimer. We are satisfied that the proposal meets the requirements of our guidance on emerging techniques for the proposed techniques for reclaiming the carbon capture solvent.	
	You must work out the solvent performance, including reclaiming requirements and emissions to atmosphere. Determine this through realistic pilot (or full scale) tests using fully representative (or actual) flue gases and power plant operating patterns over a period of at least 12 months.	The Applicant confirmed that although a pilot plant trial has not been carried out on the VPI flue gases, the solvent provider has accumulated several thousand hours of testing on various flue gases and commercial scale operation of the Cansolv D-103 solvent, including:	

		1) 5,000 hours of pilot scale testing at Fortum Oslo Varme AS (FOV) (in July 2018) to demonstrate that the Shell's Cansolv capture technology using solvent DC-103 is suitable for cleaning CO_2 from the exhaust gases of waste to energy (WtE) plant at Klemetsrud in Oslo, Norway – solvent reclaiming was not performed as part of this test. 2) 10 years operational experience at Brothers Chemical, South Africa. Commercial scale plant at 60,000 tonnes per annum processing gas boiler flue gas which is analogous to VPI's flue gas in composition. Batch reclaiming of solvent is typically performed every second month. 3) Over 6 years operating experience at SaskPower's Boundary Dam coal power plant. 1 MTPA commercial scale plant – batch reclaiming of solvent is performed. 4) Planned test campaign at TCM (Commencing Q1 2023). Target 5 months testing on CHP and refinery FCC flue gases. In their response to our Schedule 5 Notice for further information dated 16/07/2024 the following additional evidence was provided: Information was provided on 10 pilot trials using the Cansolv D-103 solvent, two of which were relevant to CCGTs. The reclaiming method to be used at VPI Immingham (separation of amine and degradation products by vacuum distillation) is the same as used in the Boundary Dam and Brother CISA commercial units. Refer to point above. On review of the response provided by the Applicant, we consider that the proposal meets the requirements of our guidance on emerging techniques in that sufficient consideration has been given to gathering information from trials and other operational experience and using this to inform the design in the scope of the proposal.	
3.3. Flue gas cleaning			
3.3.1.1	Sulphur oxides (SOx) removal can be in the power plant flue gas desulphurisation unit or in the PCC direct contact cooler. SOx in the flue gas will readily react with amines to produce heat stable salts. These products are typically stable under reclaimer conditions, but the heat stable salt formation with SOx can be, at least partly, reversed by alkali addition in the solvent reclaiming process.	The Applicant confirmed that GT1 and GT2 are natural gas-fired plant, and therefore SOx emissions are very low in this instance. When the auxiliary boilers are fired on ROG there is potential for SOx to be present in the flue gas, and therefore the DCCs will be dosed with caustic to remove SOx prior to the flue gas being introduced to the PCC plants to minimise the potential for SOx to	Y

	SOx levels will therefore affect solvent consumption but are expected to have a limited effect on emissions. For most gas and biomass fuels that have intrinsically low S levels, adding more upstream SOx removal is likely to be primarily an economic decision. SOx levels in the exit flue gases from an amine PCC plant will be at extremely low levels.	react with the amine solvent. Caustic will also be added to the thermal reclaimer to enable the separation of the amine solvent. We are satisfied that the proposal meets the requirements of our guidance on emerging techniques for SOx emissions.	
3.3.1.2	The impact of NOx in the flue gas will vary significantly with the solvent composition. If the amine blend will form significant amounts of stable nitrosamines with NOx in the flue gas, then you must reduce NOx to as low a level as practicably possible (see LCP BREF) using selective catalytic reduction (SCR).	The Applicant confirmed that based on the current NO_2 concentrations within the NOx emissions from GT1, GT2 and the auxiliary boilers, it is not considered necessary to include SCR for NOx reduction when using the Cansolv DC-103 solvent, as detailed in Section 4.2.2 of the supporting information. In their response to our Schedule 5 Notice for further information dated 16/07/2024 the following additional evidence was provided: Although SCR would have no impact on the direct emission of amines, the potential for a reduction in the NOx concentration in the flue gas has been considered in terms of the potential to reduce the generation of atmospheric N-amines following the release of amines and N-amines to air from the stacks. The level of NOx reduction that could be achieved by SCR is currently unknown. In applications where flue gases which have high NOx emissions, reductions of up to 90% can be achieved. However, the VPI flue gas already has a relatively low NOx concentration, and therefore the level of NOx reduction an SCR could achieve will be limited. In addition, the only practical SCR system is an in-duct SCR due to the limitations on space for such a retrofit (as detailed in the Main Supporting Document) and there are limited comparable operational systems from which indicative NOx emission level can be obtained. In order to remodel the N-amine impacts, NOx concentrations from the GTs have been assumed to be reduced to 30 mg/Nm^3. Previous experience for CCGTs with SCR indicates that technology providers are unlikely to provide guarantees for annual concentrations below 30 mg/Nm^3. Emission concentrations for SCR on the auxiliary boilers are also uncertain, however it has been assumed that the same NOx concentration of 30 mg/Nm^3 could be achieved from the boilers. Due to the much lower flue gas volume from the auxiliary	Y

		boilers, it is considered these sources have a minimal impact on the overall NOx mass release in any case. The previous dispersion model was rerun with the reduced NOx emissions, and it was found that it reduced the impacts of total N-amines by only 1%, compared to the revised assessment results that were presented in Appendix A of the Schedule 5 response. Given the uncertainties in the use of the ADMS amines module it is considered that such a limited reduction in the level of predicted impacts is insignificant and therefore does not support the application of SCR. We asked the Operator to provide modelling to demonstrate how adding SCR would affect the direct emissions of NO_X, amines, and nitrosamines at sensitive receptors. They stated that SCR could reduce NO_X emission concentrations from the gas turbines and auxiliary boiler to 30 mg/Nm^3, from 40 mg/Nm^3 and 100 mg/Nm^3, respectively. However, they state that SCR would have no impact on the amine and nitrosamine direct emission concentrations. It is beyond our scope to comment on the accuracy of this claim. They conducted modelling to assess the impact of the reduced NO_X emissions on the indirect formation of nitrosamines from the flue gases. They predicted that SCR would reduce the N-amine PCs by 1%. Our audit modelling agreed with the Operator's predictions and conclusions. Based on the available evidence for this case, we agree that the limited reduction of N-amine PCs does not support the implementation of SCR. Additionally, the technical complexities and the potential increase in ammonia emissions leading to an increase in nitrogen deposition on the Humber Estuary habitat site further support the case that installation of SCR is not required. We are satisfied that the proposal meets the requirements of our guidance on emerging techniques for NOx emissions.	
	If necessary, it is expected that ammonia (NH_3) slip from the SCR unit could be addressed in a suitably designed PCC unit. In all cases, you must assess the effects of NOx in the flue gas on atmospheric degradation reactions and this may also affect the need for SCR	No SCR proposed	

	If SCR is not fitted to a new build power plant, it is generally considered BAT to maintain space so it may be retrofitted in future, should this be considered necessary to meet ELVs.	Not applicable (not new build)	
3.3.1.3	Sulphur trioxide (SO_3) 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.	The Applicant confirmed that SO_3 and fine particulates are not present in the VPI flue gas. However, a mist eliminator will be located after the water wash section at the top of the absorber columns to minimise aerosol release. In addition, an antifoam skid will be installed to mitigate foaming. We are satisfied that the proposal meets the requirements of our guidance on emerging techniques for aerosols. The Applicant's monitoring proposals are set out in section 8 of this document. Based on the information provided, we are therefore provisionally satisfied that the proposed plant meets the requirements of our guidance on emerging techniques for isokinetic sampling, subject to the approval of the improvement and pre-operational conditions.	Y Subject to approval of the improvement and pre-operational conditions
3.3.1.4	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).	Not applicable	Y
	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.	The Applicant confirmed that flue gas impurities have been considered in the plant design and it has not been deemed necessary to provide further abatement other than that discussed in the Application. We are satisfied that the proposal meets the requirements of our guidance on emerging techniques for flue gas impurities.	

3.3.2. PCC system operation			
Operating temperatures			
3.3.2.1	You must establish and maintain optimum temperature and appropriate limits in the solvent stripping process. Elevated temperatures can cause some thermal degradation of the solvent. But higher peak average temperatures during regeneration will also likely promote reduced energy requirements and higher CO_2 capture levels. You must balance both to ensure the right environmental outcome. Where feasible, you should avoid locally higher metal skin temperatures, such as from the use of superheated steam in heaters, as this provides no benefit and can result in degradation.	The Applicant confirmed that the PCC plants design is such that it will operate at optimised conditions for the Cansolv DC-103 solvent. We are satisfied that the proposal meets the requirements of our guidance on emerging techniques for operating temperatures.	Y
Solvent Degradation			
3.3.2.2	You should minimise oxidative degradation of the solvent by reduced solvent residence times in the absorber sump and other hold-up areas. Direct O_2 removal from rich solvent may be developed in the future but has not yet been proven at scale.	The Applicant confirmed that the PCC plants design is such that it will operate at optimised conditions for the Cansolv DC-103 solvent. According to the information provided by the Applicant in response to a Schedule 5 Notice dated 16/07/2024 (received 26/09/2024), Shell have confirmed that the Cansolv DC-103 solvent does not degrade/ decompose when exposed to atmospheric oxygen and therefore does not need to be stored under nitrogen to prevent degradation. In relation to the degradation of the solvent we also requested additional information from the Applicant on potential accumulation of ammonia, nitrosamines and other amines degradation products in the circulating solvent and methods to limit or remove them. The Applicant's response is summarised in the following: CANSOLV DC-103 is composed of low volatility amines compared to other technologies available in the industry, and its degradation pathways favour the formation of low volatility degradation products (including organic acids, amides, formamides and nitrosamines), rather than light degradation products such as ammonia. The resulting low primary emissions of amines and degradation products for the CANSOLV system, therefore, lead to much lower accumulation in the water-wash system than for other amine systems, including MEA systems. Combined with the intrinsically low volatility, this leads to negligible equilibrium partial pressure of	Y Subject to approval of the improvement condition

		amines and degradation products exerted by the circulating water, and low residual concentrations in the gas exiting from a water-wash. As such, the low equilibrium concentration at the outlet of the water-wash means that a second wash stage would result in minimal further reduction, provided the packing height in the first stage is sufficient. It is recognised that ammonia will only be marginally captured by the water-wash, due to its high volatility and already low concentration in the flue gas. The generation of ammonia from CANSOLV DC-103 is very limited for clean gas applications, such as the VPI CHP power plant (i.e. where the flue gas does not contain contaminants such as iron, which could favour certain degradation pathways and therefore lead to higher degradation product emissions), typically of the order of a few ppmv or lower, as indicated in the proposed ELVs in Table 1 of their response. Achievement of the low ammonia emission of 2 mg/Nm^3 is therefore not reliant on capture of ammonia in the water wash, but on the inherently low emissions of the overall CANSOLV system in clean gas applications. According to the information provided by the Applicant, nitrosamines and other degradation products only tend to accumulate in the absence of reclaiming, or if the reclaiming rate is insufficient to compensate for the degradation products generation rate. The method to limit accumulation to design levels – typically 1-2% in a commercial plant – is the use of the thermal reclaimer (which has built-in spare capacity to account for unexpectedly high degradation rates). In addition, nitrosamines tend to degrade in the CO_2 stripper, due to the high temperatures present, and as such, their accumulation rate will be slowed, and may reach a steady-state plateau, even in the absence of reclamation. This is reflected in the low nitrosamine/nitramine emission level of 0.0013 mg/Nm^3 (direct emissions) proposed as an emission limit for the Application. According to the information provided by the Applicant, the emission figures are based on steady-state long term operation and account for solvent composition, and in particular degradation products concentration, in these conditions. Based on the information provided, we are therefore provisionally satisfied that the proposed plant meets the requirements of our	

		guidance on emerging techniques for solvent degradation, however we have set an improvement condition for the assessment of solvent quality over 12 months of operation so our final decision will be subject to the approval of the improvement condition.	
3.3.3. Absorber emissions abatement			
Water wash			
3.3.3.1	You must use one or two water washes or a scrubber to return amine and other species to the solvent inventory. Capture levels are limited by vapour or liquid equilibria, with volatile amines captured less effectively. Any aerosols present will also not be captured effectively. Water washes alone are ineffective in preventing NH_3 emissions, as concentrations will increase until the rate of release balances the rate of formation (and possibly addition from SCR slip).	The Applicant confirmed that there will be a single water wash section in place, which will enable solvent reuse. In addition, a mist eliminator will reduce aerosols present in the released flue gas. There is no SCR, therefore NH_3 emissions will be minimal from the operational PCC plants, limited to any generated as an amine degradation product. We are satisfied that the proposal meets the requirements of our guidance on emerging techniques for water washes.	Y
Acid wash			
3.3.3.2	An acid or other chemically active wash or scrubber after the water wash will react with amines, NH_3 and other basic species and reduce them to very low levels (for example, 0.5 to 5mg/m^3 per species or lower). You should implement an acid wash as BAT, unless: • emission levels are already at acid wash levels with a water wash • you can show that the need to dispose of the acid wash waste outweighs the benefits of the additional reduction in emissions to atmosphere Depending on PCC system configuration, an absorber acid wash can also counteract NH_3 slip from an SCR system.	The Applicant confirmed that an acid wash is not considered necessary to further reduce amine, ammonia or other pollutants from the process, based on the expected emission concentrations. In their response to our Schedule 5 Notice for further information dated 16/07/2024 the following additional evidence was provided: The limits proposed in table 1 of the Schedule 5 response (refer to section 7.3 of this document) are based on extensive solvent trials and performance guarantees by the technology provider. The Applicant confirmed that emissions are already low with reference made to a pilot plant trial (Maasvlakte) evidenced in the BAT review at BAT-for-PCC_v2_EfW_web-1.pdf (ukccsrc.ac.uk) where emissions are significantly greater. For example, the ammonia emissions from this pilot trial after the acid wash were <5 mg/m^3, with the proposed ammonia emissions from the VPI PCC absorber plant without an acid wash being 2 mg/m^3. They conclude that the proposed emission concentrations from the VPI PCC plant are therefore already considered to be “at acid wash levels with a water wash”, as they are below the “very low levels”	Y

		specified in the PCC BAT Guidance without the requirement for an acid wash. They also confirm that if an acid wash were required, this would generate a waste stream which would be difficult to dispose of. The BAT Review for PCC recognises this issue, quoting that for the Peterhead FEED study, treatment of the acid wash waste stream was likely to be “highly complex, expensive, operator intensive and would have most likely have suffered from poor reliability.” However acid wash introduces further engineering issues than just the disposal issue detailed in the BAT Review for PCC. They also confirm that the introduction of an acid wash section would result in leakage of the acid solution to the amine section of the CO_2 absorber column. Such leakage would result in formation of salts in the amine solution, and even a very limited leakage rate may require an additional salts removal system, generating a further waste stream requiring disposal. They therefore conclude that the cross-media impacts associated with the acid wash waste stream and the engineering complexities outweigh the slight reduction in emissions to air that it may provide. They confirm that the Air Impact Assessment provided in Appendix F of the Main Supporting document shows that the predicted concentrations of amines and other degradation species (including ammonia) are insignificant at all human health receptors compared to the relevant EALs. We note that amide did not screen out, refer to section 5.2.1 of this document. In terms of the impacts of N-amines, the total impacts at the worst-case receptor were predicted to be 67% of the EAL for NDMA. The modelling results are presented in section 5.2.1d of this document. The predicted ecological impacts are also considered to not be significant. They therefore consider that there is no environmental driver, in terms of the impacts of emissions to air, to reduce emissions further than that achieved by the proposed water wash. We agree that an acid wash is not required and summarise our conclusions as follows:	

- The Permit sets limits for ammonia, amines and nitrosamines proposed by the Applicant (and modelled) as follows:

Parameter	Annual average limit (mg/Nm^3)
Ammonia	2
Total amines	0.3
Total N-amines (nitrosamine and nitramines, direct release)	0.0013

- The increase in PCs of ammonia and nitrogen deposition compared to the baseline are only 3.3% and 3.9% respectively.
- The PC of acid deposition is < 1% of the ES, so is screened out as being insignificant.
- The Application assessment shows PCs for the amines that, when added together, are < 1% of our proposed EAL for piperazine.
- The PCs for total (direct and indirect) nitrosamines are not insignificant, but cumulative impacts (for VPI and Phillips 66) are <100% of the NDMA EAL at both the R2 and R8 receptors, with the cumulative impacts dominated by the emissions from VPI.
- Direct emissions of nitrosamines are unlikely to dominate the total nitrosamine PCs. Our checks indicate they make up less than half of the total. Direct nitrosamine emissions and proposed Permit limits are in keeping with other issued permits and are above the limit of detection in our evidence review of 0.2 ug/m^3 NPL REPORT CSSC 0001).
- To reduce total nitrosamine levels at receptors it would therefore be necessary to reduce the amine emissions

		which form the indirect nitrosamines, in particular the VPI amine emissions. • The Applicant's proposed limit for amine emissions of 0.3 mg/Nm^3 is already low (compared to other issued permits), and we do not currently have evidence to support a case that adding an acid wash would significantly reduce this emission concentration. • The Applicant has made it very clear in their Schedule 5 Notice response that they are confident that they can achieve their proposed limits and that they have reliable guarantees from the technology provider on which they can rely. They state that the guarantees are supported by the technology providers experience with Cansolv solvent used in prolonged operations at Brother CISA and Boundary Dam developments. • The Applicant also made it clear that the solvent reclaiming process (continuous thermal/vacuum distillation) will prevent significant solvent breakdown, which would increase amine, ammonia and nitrosamine emissions and prevent build-up of nitrosamines above 1-2% in the circulating solvent. The reclaiming process has been designed with additional capacity to allow for a higher rate of solvent degradation than expected. • If, at commissioning/early operation, solvent breakdown and associated increased emissions of ammonia, amines or direct emissions of nitrosamines become an issue, the Operator will need to review options to address this. The options should include increasing the rate of solvent reclamation as per their own proposals. • The Applicant acknowledges that there will be other future developments in the vicinity of their processes (Stallingborough CCGT and Humber H2ub Blue H2) but have not included these developments in their cumulative assessment as there is no relevant information on any	

		solvents which may be used. We agree that this is the case. Although according to our guidance we would normally consider the inclusion of acid wash to be BAT, in this case we have decided that the additional information provided by the Applicant is sufficient to justify not including this abatement stage in the proposed carbon capture plant at the Humber Refinery. Our decision is based on the information available at this stage and on the conclusions of the air emissions risk assessment, in combination with the proposed carbon capture plant at the nearby Humber Refinery. We note that the proposed emission levels are already relatively low and in keeping with the emission performance claimed to be attainable by other carbon capture applications we have received and assessed. We do not currently have evidence to support a case that adding an acid wash would significantly reduce these emissions. The Applicant has made it very clear in their Schedule 5 Notice response that they are confident that they can achieve their proposed limits and that they have reliable guarantees from the technology provider on which they can rely. The Applicant also made clear that the solvent reclaiming process will prevent significant solvent breakdown (which would increase amines, ammonia and nitrosamine emissions) and prevent build-up of nitrosamines in the circulating solvent, and that the reclaimer process has been designed with additional capacity to allow for a higher rate of solvent degradation than expected. We consider that, if at commissioning/early operation solvent breakdown and associated increased emissions of ammonia, amines or direct emissions of nitrosamines become an issue, the Operator will need to address this to ensure that the proposed emission limits are attained.	

		One of the options will consist of increasing the rate of solvent reclamation as per their own proposals. In the Schedule 5 Notice served to the Applicant, we asked whether they were including provisions to make it technically and economically feasible to retrofit an acid wash stage, with limited intervention, should the actual operating performance of the plant warrant so (such as pre-engineering the additional space/column height required to include additional washing stages and acid wash, column design compatible with retrofitting internals required for acid wash and selecting materials of construction compatible with acid wash, if applicable). The Applicant has assessed that allowing provisions to retrofit acid wash is not necessary, based on the reassurance and performance guarantees provided by solvent technology licensor. We consider that setting the stringent emission limits in the Permit proposed by the Applicant will provide an appropriate level of environmental protection. We will require the Applicant to comply with the emission limits stated in the Application and specified in the Permit.	
	If an acid wash is not fitted, you should consider a second water wash as an acid wash if: • emissions performance is worse than expected • you wish to change to a more volatile solvent An acid wash is not likely to trap aerosols.	The Applicant confirmed that: CANSOLV DC-103 is composed of low volatility amines compared to other technologies available in the industry, and its degradation pathways favour the formation of low volatility degradation products (including organic acids, amides, formamides and nitrosamines), rather than light degradation products such as ammonia. The resulting low primary emissions of amines and degradation products for the CANSOLV system therefore, lead to much lower accumulation in the water wash system than for other amine systems, including MEA systems. Combined with the intrinsically low volatility, this leads to negligible equilibrium partial pressure of amines and degradation products exerted by the circulating water, and low residual concentrations in the gas exiting from a water wash. As such, the low equilibrium concentration at the outlet of the water wash means that a second wash stage would result in minimal	Y

		further reduction, provided the packing height in the first stage is sufficient. It is recognised that ammonia will only be marginally captured by the water-wash, due to its high volatility and already low concentration in the flue gas. The generation of ammonia from CANSOLV DC-103 is very limited for clean gas applications, such as the VPI CHP power plant (i.e. where the flue gas does not contain contaminants such as iron, which could favour certain degradation pathways and therefore lead to higher degradation product emissions). Achievement of the low ammonia emission is therefore not reliant on capture of ammonia in the water wash, but on the inherently low emissions of the overall CANSOLV system in clean gas applications. In both the Boundary Dam and the Brothers CISA unit, in operation since 2014, the treated gas washing section is composed of a single stage water wash and no acid wash. Further, long-term pilot tests have shown that outside of contaminated applications (i.e. where iron and/ or aerosols are present), a single stage water wash achieves the emission levels detailed in section 7.3 of this document. The most relevant campaigns are the most recent ones, which have employed advanced monitoring instrumentation to respond to an increasing demand for data on emissions. The findings of these pilot tests have been reported in the following public presentations/ articles, which were provided in Appendix B of the Schedule 5 response: Oslo Klemetsrud piloting campaign – 2019 Oslo Klemetsrud piloting campaign – 2021 TCM demonstration campaign – 2023 They therefore consider that the data held by the technology provider supports the conclusion that simple water wash, in absence of acid wash, will be sufficient to abate amines and solvent degradation products such that the emission levels set out in section 7.3 of this document can be met.	

		Regarding uncertainties of the design in relation to efficiency of the absorber emissions abatement system, they confirm that the main provision to manage any uncertainty in the design is a significant margin in the Thermal Reclaimer processing capacity, which will ensure that degradation products, such as nitrosamines do not build up in the solvent. It is considered that the design uncertainties are limited for this application of the carbon capture technology and therefore no further provision for future retrofit of additional wash stages is considered necessary. As above, we consider that setting the stringent emission limits in the Permit proposed by the Applicant will provide an appropriate level of environmental protection. We will require the Applicant to comply with the emission limits stated in the Application and specified in the Permit.	
Droplet Removal			
3.3.3.3	You must prevent emissions of aerosols. To do this you could use standard droplet removal sections after washes. These will prevent droplet carryover from the wash. However, they are not effective against very fine aerosols arising from SO_3 or other aerosol mists.	The Applicant confirmed that a mist eliminator will be located at the top of water wash section to prevent the entrainment of droplets into the waste gases. We are satisfied that the proposal meets the requirements of our guidance on emerging techniques for droplet removal.	Y
Stack Height			
3.3.3.4	Where modelling predicts that you may need to raise the temperature at the point of release to aid dispersion, you can: • increase the design stack height • add flue gas reheating Flue gas reheating can also reduce the plume visibility. Heat from cooling the flue gas before the PCC plant or waste heat from the PCC process should be used for flue gas reheating (see section 4 on cooling)	The Applicant confirmed that detailed dispersion modelling has shown that a stack height of 110m for the PCC plants will result in no exceedance of any air quality standards for pollutants released. On the basis of the model results, it is not considered that flue gas reheating is required. Refer to section 5 for the risk assessment of emissions to air. We are satisfied that the proposal meets the requirements of our guidance on emerging techniques in this regard.	Y

3.4. Process and emissions monitoring			
Role of monitoring			
3.4.1	The main purpose of monitoring the PCC process is to show that the emissions from the process, primarily to air, are not causing harm to the environment. You must also carry out monitoring to show that resources are being used efficiently. This includes: • energy and resource efficiency • capture efficiency • verification that the CO_2 product is suitable for safe transport and storage Your permit application should include a monitoring plan for both a commissioning phase and routine operation. During the commissioning phase you will need to optimise the operating envelope for the process. When you have achieved this the process operation will then become routine, along with the monitoring. It's likely you'll need to do more extensive monitoring during commissioning than during routine operation. As PCC is an emerging technique, you will need to develop monitoring methods and standards. You should include proposals for this in your permit application. Compliance with ELVs in the permit will provide the necessary protection for the environment, by monitoring emissions at authorised release points. You must also show that you're managing the process to prevent (or minimise) the formation of solvent degradation products. Where degradation products are formed (and may be released), you must reduce these and any solvent emissions to the appropriate level. This process control monitoring will also be part of the permit conditions.	The Applicant confirmed that the Installation is already required to monitor and report energy and resource efficiency figures. The PCC plants operation will also be equipped with the capability to monitor continuously and to report the resource and energy efficiency of the plant. We have set a pre-operational condition in the varied Permit for a commissioning plan which includes the requirement for the Applicant to confirm: • a methodology to demonstrate carbon capture efficiency; and • the additional monitoring that will be carried out at the commissioning phase. They conclude that further work is required to identify appropriate monitoring techniques. They propose that this is addressed via a pre-operational condition in the Permit requiring confirmation of proposed monitoring techniques for amines and degradation products from the PCC plants prior to their commissioning. We have included this in the above pre-operational condition in the Permit. In their response to our Schedule 5 Notice for further information dated 16/07/2024 they proposed to undertake the following process monitoring: Weekly (with increased frequency (daily) on start-up) on-site (by operator): • opacity/ colour • solvent concentration • CO_2 loading • foaming tendency Weekly at start-up, monthly to quarterly in steady-state operation off-site in a Shell laboratory or accredited laboratory (or on-site if Operator acquires the required analytical equipment): • amine and organic non-ionic degradation products by liquid chromatography-mass spectrometry (LCMS) • organic acids and salts by ionic chromatography	Y Subject to approval of the pre-operational condition

		- metals by inductively coupled plasma (ICP) They confirmed that although colour / opacity monitoring will be carried out, it does not necessarily correlate with solvent health and / or performance. Colour would be viewed as an indicator, rather than a reliable parameter. Process control monitoring has been set in table S3.4 of the Permit to ensure that degradation products do not build up in the PCC plants, as advised by the solvent supplier based on their operational experience. However, we changed the monitoring frequency from that proposed by the Applicant, for the heat stable salts as set out below: Heat stable salts - Every day during the first month of operation then once per week, or otherwise agreed in writing with the Environment Agency. This is consistent with other carbon capture permits we have issued, and we consider the increased frequency is more appropriate to the risks associated with the potential degradation of the solvent. We have also included weekly monitoring for soluble iron concentration in the rich amine and the lean amine (following the stripper). We have included these as we consider iron is a good indicator of degradation. We are satisfied that the proposal meets the requirements of our guidance on emerging techniques in this regard, subject to approval of the pre-operational condition.	
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.	The Applicant confirmed that a continuous emission monitoring system (CEMS) for monitoring of combustion gases from the PCC plants will be installed. In addition, the existing CEMS on the GT1, GT2 and auxiliary boiler emission points A1 to A4 will be maintained for in the event that the Installation is required to operate in CO_2 unabated mode. It is intended that CEMs monitoring of these species will be included for the PCC plants, however the exact specification of equipment to monitor the amines and degradation products is yet to be confirmed. If no suitable equipment is available, these will be monitored by periodic extractive monitoring. We have set the necessary monitoring requirements and emissions limits in tables S3.1 and S3.1a of the Permit. The Applicant confirmed that emission sampling locations will comply with M1 guidance as far as is possible. Additional information was provided in their responses to our Schedule 5 Notice for further information dated 16/07/2024, refer to section 8 of this document. We have included an improvement condition in the Permit requiring the Operator to confirm that sampling points are compliant. We are satisfied that the proposal meets the requirements of our guidance on emerging techniques in this regard, subject to approval of the improvement condition.	Y Subject to approval of the improvement condition
3.4.3. Process control monitoring			
	You should use process control monitoring or periodic sampling with off-line analysis to control the CO_2 capture and the quality of the solvent reclaiming. Parameters you can monitor include: • absorber solvent quality – percentage active solvent • CO_2 loading both rich and lean solvent • maximum solvent temperature • heat stable solvent content • solvent colour or opacity • soluble iron and other metals and degradation products	The Applicant confirmed that the PCC plants will include instrumentation to monitor and record CO_2 capture rates and purity. Sampling points will be provided to collect fluid samples of the solvent to ensure the quality of solvent reclaiming and maintain the appropriate dilution ratio. We have set the necessary process monitoring requirements in table S3.4 of the Permit, refer to section 3.4.1 of this table. We are satisfied that the proposal meets the requirements of our guidance on emerging techniques for process control monitoring, subject to approval of the pre-operational condition.	Y Subject to approval of the pre-operational condition

	- in water or acid washes and scrubbers – pH, conductivity, loading of abated substances, flow rate		
Monitoring of CO_2			
3.4.4	To meet the required specification, include: - CO_2 mass balance - CO_2 in fuel combusted - total capture level (as a percentage) - CO_2 released to the environment - CO_2 quality	The Applicant confirmed that these parameters will be monitored as part of the PCC plants operation. We have included the necessary monitoring requirements in table S3.4 of the Permit, which includes: - Exported CO_2 mass flow (tonnes/hour) - Composition of exported CO_2, including but not necessarily limited to: • water content • hydrogen content We have also specified a pre-operational condition to confirm the process monitoring methods. We are satisfied that the proposal meets the requirements of our guidance on emerging techniques for CO_2 monitoring, subject to approval of the pre-operational condition.	Y Subject to approval of the pre-operational condition

Monitoring Standards			
3.4.5	The person who carries out your monitoring must be competent and work to recognised standards such as the Environment Agency's monitoring certification scheme (MCERTS). MCERTS sets the monitoring standards you should meet. The Environment Agency recommends that you use the MCERTS scheme where applicable. You can use another certified monitoring standard, but you must provide evidence that it is equivalent to the MCERTS standards. There are no prescriptive BAT requirements for how to carry out monitoring. Monitoring methods need to be flexible to meet specific site or operational conditions. You must use a laboratory accredited by the United Kingdom Accreditation Service (UKAS) to carry out analysis for your monitoring.	The Applicant confirmed that any extractive monitoring carried out on the emissions from the PCC plants will be carried out by MCERTS accredited contractors. They also confirmed that where required and available, UKAS accredited laboratories will be used for analysis. We have included the necessary monitoring requirements in tables S3.1 and S3.1a of the Permit. We are satisfied that the proposal meets the requirements of our guidance on emerging techniques for monitoring standards.	Y
3.5. Unplanned emissions to the environment			
3.5.1	You should propose a leak detection and repair programme that is appropriate to the solvent composition. This should use industry best practice to manage releases, including from joints, flanges, seals and glands. Your hazard assessment and mitigation for the plant must consider the risks of accidental releases to environment. This should also consider the actual composition of the fluids, gases and vapours that could be released from the plant after an extended period of operation. (Not only fresh solvent as initially charged.)	The Applicant confirmed that the PCC plants will be part of the Installation's maintenance programme and will include instrumentation to detect and monitor any leaks. Any leaks identified will be repaired by licenced contractors. A leak detection and repair (LDAR) system will be put in place for the PCC plants. The CO_2 compression systems are provided with a single CO_2 vent stack for the safe release of CO_2 to atmosphere. Any venting of CO_2 will be in line with applicable Health and Safety Executive (HSE) guidelines. The plant will be fitted with equipment with gas detection devices which will be linked to the site fire and gas system. We have included an improvement condition in the Permit for the LDAR programme. We have also included pre-operational conditions for the EMS to be updated and for a CO_2 venting management plan to be submitted. Also refer to the following sections of this document: • 3.4 - The site and its protection; • 5.6.1- Emissions to water; and	Y Subject to approval of the improvement and pre-operational conditions

		- 5.6.2 - Fugitive emissions. We are satisfied that the proposal meets the requirements of our guidance on emerging techniques for unplanned emissions, subject to approval of the improvement and pre-operational conditions.	
3.6. Capture level, including during flexible operation			
3.6.1	Capturing at least 95% of the CO_2 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 CO_2 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.	Refer to section 3.1.1 of this table. We are satisfied that the proposal meets the requirements of our guidance on emerging techniques in this regard.	Y

3.6.2	You should set out any potential ‘other than normal operating conditions’ (OTNOC) for the CO_2 capture plant in your permit application. You should include PCC OTNOC management plan in your management system to measure and minimise occurrence and impact of these periods. OTNOC includes periods of start-up and shutdown. Your PCC OTNOC management plan must compliment any OTNOC management plan for the facility it serves and consider internal and external causes of OTNOC. An example of OTNOC would be when the CO_2 transport and storage network is down.	The Applicant confirmed that the EMS details controls in place to reduce emissions to air and/ or water during OTNOC that includes the following: • set-up and implementation of a specific preventive maintenance plan for these relevant systems; • review and recording of emissions caused by OTNOC and associated circumstances and implementation of corrective actions if necessary; and • periodic assessment of the overall emissions during OTNOC (e.g. frequency of events, duration, emissions quantification/ estimation) and implementation of corrective actions if necessary. They also confirm that the management system will be amended to include the PCC plants prior to commencement of operations. We have included a pre-operational to address this. We have also set a pre-operational condition requiring the Applicant to include proposals in their PCC commissioning plan for OTNOC to monitor carbon capture performance during these periods. Refer to section 8.3 of this document. We are satisfied that the proposal meets the requirements of our guidance on emerging techniques in this regard, subject to approval of the pre-operational conditions.	Y Subject to approval of the pre-operational conditions
3.6.3	As the fraction of intermittent renewable generation in the UK rises, many CCS enabled plants will need to start and stop more often, and possibly also operate at variable loads. It is therefore important, for current or future intermittent operation plant, that you aim to maximise CO_2 capture during these periods, including during start-up and shutdown, to maintain high average capture levels. You should therefore capture CO_2 during plant start-up and shutdown as part of using BAT. A method to maintain capture during start-up and shutdown using solvent storage has been identified in chapter 7 of the PCC evidence review. This, or alternatives that can achieve equivalent results, is considered BAT. You will need to provide justification and a cost benefit analysis if you are not proposing capture during start-up and shutdown.	The Applicant confirmed that the plant is a CHP, providing heat and power to the adjacent refineries and therefore required to be in continuous operation. Future operation will likely be flexible, i.e. ramping up and down instead of starting and stopping. Therefore, variable loads are less likely to impact capture rates. There will be minimal start-up and shut-downs. In addition, due to the availability of steam which can be easily used to start the capture plant and make it ready to accept flue gas, no special design measures are required to speed up start-up rate. We are satisfied that the proposal meets the requirements of our guidance on emerging techniques in this regard.	Y

	If your PCC plant is not initially constructed with this capability, your permit application should show how you may retrofit it. Your PCC OTNOC management plan should include measures to minimise any CO_2 emitted during start-up and shutdown periods. Some plants (including EfW) may not have frequent start-ups and shutdowns, so investment in solvent storage (or an alternative) is likely to be an economic decision. You should outline this in your cost benefit analysis. Where the CO_2 is being captured for secure geological storage, the transport and storage system may not always be available. When it is not, it is not appropriate to capture CO_2. You will need to make sure the PCC plant is bypassed so that electricity, CHP generation or waste incineration can continue. You must not include these periods in any capture efficiency calculation, but you must keep a record of these, and CO_2 quantities emitted for reporting purposes. The CO_2 transport and storage system (including non-pipeline transfer) may sometimes need to be constrained – that is, it cannot take all the CO_2 you are producing. You should plan how you would meet this constraint as far as is practicable. You should detail both situations in your permit application. You must show how you will manage the plant to minimise emissions to the environment, including during start-up and shut-down.		
3.7. Compression			
3.7.1	You should select CO_2 compressors based on the expected duty. You should consider how any waste heat arising may be used. For base load operation, you should use integrally geared units because they give the: • maximum full-load efficiency minimum number of compression trains For flexible and part-load operation, smaller compression trains (for example 2 at 50% compared to 1 at 100%) may be preferable. The use of different types of compressor or pump in series may also be preferable, to give greater flexibility at the expense of slightly lower full-load efficiencies.	The Applicant confirmed that the PCC plants will comprise geared compressors to carry out both the low- and high-pressure compression of the CO_2. The compressor selection has been undertaken based on the anticipated load(s). They also confirmed that integrally geared units are proposed, as the Installation is a base loading plant. The requirement for flexible and part-load operation are not applicable as this is a base loading plant. We are satisfied that the proposal meets the requirements of our guidance on emerging techniques for compression.	Y

3.8. Noise and odour			
3.8.1	The LCP BREF already covers noise impacts for the main power plant. You only need to consider additional process steps in PCC technology that have high potential for noise and vibration. In particular, CO_2 compression could be an area of concern. Once you've identified the main sources and transmission pathways, you should consider the use of common noise and vibration abatement techniques and mitigation at source wherever possible. For example, the: • use of embankments to screen the source of noise • enclosure of noisy plant or components in sound-absorbing structures • use of anti-vibration supports and interconnections for equipment • orientation and location of noise-emitting machinery • change of the frequency of the sound	The Applicant confirmed that a noise impact assessment (NIA) has been undertaken in support of the Application, and includes an assessment of all potential sources of noise from the PCC plants, including but not limited to the compressors. Specific noise attenuation measures are yet to be confirmed for the project, however these will be confirmed with us in the detailed design phase. Our review of the NIA is provided in section 5 of this document. A pre-operational condition has been included in the Permit requiring a review of the NIA and noise management plan (NMP) to be submitted following final design of the PCC plants. We are satisfied that the proposal meets the requirements of our guidance on emerging techniques for noise, subject to approval of the pre-operational condition.	Y Subject to approval of pre-operational condition
3.8.2	The handling, storage and use of some amines may result in odour emissions, so you should always use best practice containment methods. Where there is increased risk that odour from activities will cause pollution beyond the site boundary, you will need to send an odour management plan with your permit application	The Applicant confirmed that the solvent will be stored appropriately to ensure minimal odour emissions. The Cansolv DC-103 solvent has a very low volatility and therefore is not considered to represent a particular odour risk. Our reviews of solvent storage and impacts from odour are provided in sections 5.6.2 and 5.6.3 respectively of this document. Pre-operational conditions have been included in the Permit for solvent storage arrangements and for an odour management plan (OMP) to be submitted following final design of the PCC plants. We are satisfied that the proposal meets the requirements of our guidance on emerging techniques in this regard, subject to approval of the pre-operational condition.	Y Subject to approval of pre-operational conditions

4. Cooling			
4.1	You will be able to achieve the best power and CO_2 capture plant performance by using the lowest temperature cooling available. You should use the hierarchy of cooling methods as follows: • direct water cooling (such as seawater) • wet cooling towers • hybrid cooling towers • dry cooling – direct air-cooled condensers and dry cooling towers	The Applicant confirmed that an assessment of potential cooling options was considered for the PCC plants, comprising air cooled, water cooled and hybrid cooling systems to determine which represents BAT for the PCC plants. The assessment is presented in Appendix E of the Application Main Supporting Document, dated December 2023 and concludes that air cooled systems represent BAT for the PCC plants. Our assessment of this is detailed in section 6.1.3 of this document. This assessment is based on the preliminary design which may be subject to change. We have set a pre-operational condition for the choice of cooling system to be confirmed for the final design. We are satisfied that the proposal meets the requirements of our guidance on emerging techniques for cooling, subject to approval of the pre-operational condition.	Y Subject to approval of pre-operational condition
4.2	Power plants that are retrofitted with PCC using steam extraction, or are intended to be able to operate without capture, can share water cooling between the power plant and the PCC system. This is because the cooling load on the main steam condensers falls with increased steam extraction rate. This shift away from condenser cooling will not apply for systems with direct air-cooled condensers. It may also be possible to reuse cooling water after the main condensers for higher-temperature cooling applications in the PCC plant. However, site specific water discharge temperature limits may be an issue for direct cooling.	The Applicant confirmed that the option to share water with the VPI CHP Power Plant cooling system was investigated but discounted. The CHP power output is constrained by insufficient cooling when the CHP is required to operate in unabated mode whilst the PCC plant is in standby / short duration outage. In this scenario, the cooling water circulation for the PCC plants will be kept online. We are satisfied that the proposal meets the requirements of our guidance on emerging techniques in this regard.	Y
4.3	A feature of PCC is that you have to remove heat from a flue gas stream that was originally not cooled. You can still achieve rejection of heat to atmosphere by heating the flue gas leaving the absorber, using heat from the incoming flue gas. You can do this either: • directly – such as using a rotary gas-gas heater • indirectly – such as using a heat transfer fluid or low-pressure steam	The Applicant confirmed that dispersion modelling has demonstrated that flue gas reheat is not required to aid dispersion of the emissions from the absorbers. Heat from the flue gas stream is low grade, and there are no opportunities to reuse this heat elsewhere. We are satisfied that the proposal meets the requirements of our guidance on emerging techniques in this regard.	Y

4.4	Lean and rich solvent storage may also help you achieve satisfactory PCC performance during periods of high cooling demand.	The Applicant confirmed that the VPI CHP Power Plant maintains a baseload production of steam which is available for start-up. Amine storage is therefore not required to improve start-up time. We are satisfied that the proposal meets the requirements of our guidance on emerging techniques in this regard.	Y
4.5	You should refer to the Environment Agency's evidence on cooling water options for the new generation of nuclear power stations in the UK when considering options for cooling. This gives an overview of UK power station cooling water systems in use in the UK and abroad.	The Applicant confirmed that this guidance was used in the preparation of the Cooling BAT assessment provided in Appendix E of the Application Main Supporting Document, dated December 2023. We are satisfied that the proposal meets the requirements of our guidance on emerging techniques in this regard.	Y
5. Discharge to water			
5.1	For discharges to water, you should refer to the guidance on surface water pollution risk assessment for your environmental permit. For best practice in plume dispersal modelling, see the Joint Environmental Program report 'A protocol on projects modelling cooling water discharges into TrAC waters within power station developments'	The Applicant confirmed that only uncontaminated water will be discharged from the PCC plant areas. Refer to section 5.6 of this document. We are satisfied that the proposal meets the requirements of our guidance on emerging techniques for discharges to water.	Y

6.1.2 Hydrogen production by electrolysis of water for treatment of CO_2

Section 4.2 of the Main Supporting Documents to the Application states: Prior to dehydration, oxygen is removed in a palladium / platinum deoxygenation unit using hydrogen produced on site by the dissociation of water.

Hydrogen produced on site falls under the following IED Schedule 1 listed activity description:

Section 4.2 Part A(1)(a)(i) - Producing inorganic chemicals such as gases: hydrogen

In their response to our Schedule 5 Notice requesting information dated 20/08/2024, the Applicant provided a review of their proposed operating techniques for hydrogen production against our guidance:

Hydrogen production by electrolysis of water: emerging techniques - GOV.UK (Hydrogen production by electrolysis of water: emerging techniques - GOV.UK (www.gov.uk)).

Based on the very small scale of the hydrogen production facility (0.6-6 kg/hr with a power demand of 300 kW) and its purpose being to deoxygenate the CO_2, we are satisfied that the fundamental requirements of the guidance are met.

In their response they confirmed that the hydrogen production plant will be operated within the low impact installation criteria of a standard rules permit.

It is not possible for the Applicant to apply for a low impact standard rules permit for the hydrogen production activity because we cannot consider a low impact installation as a subset of a larger installation permit. The Applicant demonstrated that the hydrogen production in isolation would in principle meet all the low impact criteria. We agreed with this approach and considered that the level of technical assessment to complete the determination would be no more than what would be required if the hydrogen production was a low impact installation in isolation.

We are satisfied that the principle of the low impact criteria has been met, and we have incorporated the low impact criteria into table S1.2 of the Permit.

Any change that would increase hydrogen production operations above the low impact criteria would require a variation for this activity.

6.1.3 Choice of cooling system

The Applicant considered the following cooling options in their BAT assessment provided in Appendix E of the Application Main Supporting document, dated December 2023:

- Option A - wet cooling tower (indirect) (mechanical draught towers) system
- Option B - dry air-cooling system
- Option C - once–through cooling (open loop wet cooling) system
- Option D – hybrid system (water and air coolers sharing the duties)
- D1 – minimum water make-up
- D2i – air cooled PCC plants, open loop water cooled CO_2 compressor
- D2ii – air cooled PCC plants, closed loop water cooled CO_2 compressor
- D3 – water cooled PCC plants, air cooled CO_2 compressor.

They confirm that whilst both air- and water-cooling systems are widely used across industries, based on the review of various operating parameters, energy efficiency and environmental effects, BAT for cooling for the PCC plants at the Installation is considered to be dry air-cooling (option B).

They also recognised as part of the BAT assessment that water availability is constrained in the Humber region, that the Humber Estuary is an internationally designated site and that there is currently no outfall from the Installation suitable for the discharge of spent cooling water.

However, they also recognise that some specialist equipment associated with the PCC plants (e.g. CO_2 compressors) will require a detailed study by the chosen suppliers to determine the final optimal cooling system. Therefore, closed loop water cooled systems and direct air cooling will both remain viable alternatives, pending the selection of equipment suppliers in the detailed design phase.

We have set a pre-operational condition requiring a review of the cooling BAT assessment, in the event that the chosen option changes following detailed design.

7. Emission limits

7.1 LCP188 - Existing CEMs for CO_2 unabated operation (A1 to A4)

For the existing CEMs to be used during CO_2 unabated operation, the Permit limits remain unchanged from existing limits and are included in table S3.1a of the Permit.

7.2 LCP188 - New CEMs for CO_2 abated operation (A6 & A7)

For the new CEMs to be used during CO_2 abated operation, the Permit limits remain unchanged from existing limits and are included in table S3.1 of the Permit. This is because the Applicant has proposed to monitor combustion emissions (refer to monitoring section of this document) from the GTs and auxiliary boilers prior to their introduction into the PCC plants.

In this case, with monitoring taking place prior to the PCC plants, there is no need to normalise limits to take into account the reduction in volume of the gas from the removal of CO_2.

A note to table S3.1 confirms that to demonstrate compliance with Chapter III of the IED and the LCP BAT Conclusions for air emissions from GT1, GT2, AB1 and AB2, monitoring shall be undertaken at a compliant location before the flue gases are discharged to the PCC Plant 1 and Plant 2 absorber columns. .

7.3 Absorber stacks CO_2 abated operation (A6 & A7)

We have set emission limits to air for when the plant is operating in CO_2 abated mode in table S3.1 of the Permit. The limits apply to emissions of treated exhaust gases from the PCC absorber stacks.

Whilst the Applicant proposed limits based on annual averages, we have set limits based on the 'Average over the sampling period', consistent with other permits in this sector. Annual averages generally apply where continuous monitoring is in place. We have retained the numerical limits proposed by the Applicant and used in the modelling of air impacts.

Regarding ammonia, whilst a certified continuous emission monitoring system (CEMS) is available (see below), the limit has been set for periodic monitoring as there is currently only one analyser available that is accurate at these low ammonia concentrations.

Regarding the other parameters, there are currently no certified CEMS for these parameters.

Whilst impacts from ammonia, total amines, acetaldehyde and formaldehyde are screened out as insignificant, we have set limits based on the concentrations used in the modelling of air impacts. This approach is consistent with other permits in the sector.

We have also set limits for total nitrosamines and nitramines (N-amines) and total amides and formamides based on the concentrations used in the modelling of air impacts. This approach is consistent with other permits in the sector and emissions for these parameters do not screen out as insignificant.

The Applicant assessed the impacts from acetonitrile, acetone and ethanol which screened out as insignificant. This was provided in their response received 26/09/2024 to our schedule 5 Notice dated 16/07/2024. We did not set limits for these parameters as emissions screened out as insignificant and we have not required limits for these substances in other permits in the sector.

The Applicant did not assess the impacts from acetate, however it was confirmed as a solvent degradation product in table A2 of the AQA. We have not included any limits, consistent with other permits in the sector. The requirements of the linked improvement condition will ensure that impacts from acetic acid are assessed with any necessary remedial actions implemented.

Parameter	Reference Period	Permit limit (mg/m^3) Notes 1 and 2
Ammonia	Average over the sampling period	2
Total amines [Note 3]	Average over the sampling period	0.3
Total N-Amines [Note 4]	Average over the sampling period	0.0013
Acetaldehyde	Average over the sampling period	0.2
Formaldehyde	Average over the sampling period	0.07
Total amides and formamides	Average over the sampling period	0.03

Note 1: No BAT AELs apply to these parameters, therefore emission limits reflect the emission concentrations proposed by the Applicant and used in the air quality assessment (AQA). The AQA confirms that these concentrations are at normalised conditions in dry air at a temperature of 273K, at a pressure of 101.325 kPa and with an O_2 content of 15% (gas turbines comprise the majority of air flow).

Note 2: Permit limits consistent with those used to assess impacts in table 4-2 of the AQA and in table 6.1 of the main supporting document. Also refer to section 8 of this document.

Note 3: Total amines includes all amines, not just amines1, 2 and 3 identified by the Applicant.

Note 4: Total N-amines include nitrosamines and nitramines.

7.4 Emissions to water (W2)

There is no requirement to set emission limits for this uncontaminated effluent discharge.

8. Monitoring and reporting

8.1 Emissions to air

8.1.1 Existing CEMs for LCP CO_2 unabated operation (A1 to A4)

CEMS are currently in place on the emission points for GT1, GT2, AB1 and AB2 monitoring the following parameters:

NOx, CO, SO_2 (AB1 and AB2 only), particulates (AB1 and AB2 only), O_2, water vapour, and temperature.

The existing CEMS will remain in place and be maintained so that they can be used in the event that the PCC plants are off-line and emissions need to be directed to the existing emission points A1 to A4.

We have included the necessary monitoring requirements in table S3.1a of the Permit.

8.1.2 New CEMs for LCP CO_2 abated operation (A6 & A7)

BAT AELs and IED chapter III limits for CCGTs and boilers differ, due to the different technologies resulting in different emission concentrations and also the reference conditions used to calculate released emission concentrations differ. As each PCC plant will take the flue gases from one GT and one auxiliary boiler it will not be possible to demonstrate ongoing compliance with the relevant AELs and limits if these were monitored at the PCC plant absorber stacks.

The Applicant proposes to monitor combustion emissions from the GTs and auxiliary boilers prior to their introduction into the PCC plants and therefore no change to the emission limits applied in the existing Permit are required (refer to emission limits section of this document).

We have included the necessary monitoring requirements in table S3.1 of the Permit. Whilst the emissions will be released via new emission points A6 and A7, a note to the table confirms that to demonstrate compliance with Chapter III of the IED and the LCP BAT Conclusions, monitoring shall be undertaken before the PCC Plant 1 and Plant 2 absorber columns.

8.1.3 CEMs and periodic monitoring for absorber stacks CO_2 abated operation (A6 & A7)

There will be no formation of NOx, CO, SO_2 or particulates within the CO_2 absorber and therefore there is no requirement for further monitoring for these pollutants from the CO_2 absorber stacks. Only monitoring for any additional pollutant species that result from the PCC plants need to be monitored on exit from the PCC plant stacks at new emission points A6 and A7. Additional pollutant species include ammonia, amines, N-amines, acetaldehyde, formaldehyde and amide.

The Applicant is investigating appropriate monitoring techniques for amines and degradation products. We have included a pre-operational condition in the Permit to address this which includes how the standards will comply with our guidance for monitoring stack emissions: carbon capture plants with solvent-based abatement (Monitoring stack emissions: carbon capture plants with solvent-based abatement - GOV.UK).

Ammonia - whilst the Applicant proposed continuous monitoring for ammonia, we have only included periodic monitoring, with the ammonia Permit limit based on periodic monitoring (see above). Ammonia monitoring is only required for the emissions from the PCC plants absorbers as there is no upstream source of ammonia from SCR or SNCR as this abatement is not in place. There is also currently only one MCERTS certified CEMS that meets the certification range requirements for the limit of 2 mg/m^3. We have therefore set the most appropriate periodic monitoring standard.

Total amines - the Applicant proposed continuous monitoring if suitable CEMS are developed by the start-up of the PCC plants, otherwise periodic monitoring. The Permit requires periodic monitoring, consistent with other permits in the sector. We have also included monitoring for the specific amines, 1-piperazineethanol, piperazine and 1,4-piperazinediethanol.

MEA - we have included periodic monitoring for MEA as the Applicant identified this as a possible solvent degradation product in table A2 of the AQA.

Total N-amines - the Applicant proposed continuous monitoring if suitable CEMS are developed by the start-up of the PCC plants, otherwise periodic monitoring. The Permit requires periodic monitoring, consistent with other permits in the sector. We have also included monitoring for specific N-amines, 4-nitroso-1-piperazineethanol and 1-nitrosopiperazine. The Applicant identified these as solvent degradation products in table A2 of the AQA.

Heterocyclic organic compounds - we have included periodic monitoring for 4-(2-hydroxyethyl) piperazin-2-one, piperazin-2-one, 1-formyl-4-(2-hydroxyethyl) and 1-formylpiperazinepiperazine. The Applicant identified these as solvent degradation products in table A2 of the AQA.

Total amides and formamides – for amides, the Applicant proposed continuous monitoring if suitable CEMS are developed by the start-up of the PCC plants, otherwise periodic monitoring. The Applicant confirmed that total amides also includes formamides. The Permit requires periodic monitoring for total amides and formamides.

Acetaldehyde - the Applicant proposed continuous monitoring if suitable CEMS are developed by the start-up of the PCC plants, otherwise periodic monitoring. The Permit requires periodic monitoring, consistent with other permits in the sector.

Acetone – the Applicant did not propose monitoring. We have included periodic monitoring as this is a confirmed as a possible degradation product.

Acetonitrile – the Applicant did not propose monitoring. We have included periodic monitoring as this is a confirmed as a possible degradation product.

Ethanol – the Applicant did not propose monitoring. We have included periodic monitoring as this is a confirmed as a possible degradation product.

Formaldehyde - the Applicant proposed continuous monitoring if suitable CEMS are developed by the start-up of the PCC plants, otherwise periodic monitoring. The Permit requires periodic monitoring, consistent with other permits in the sector.

Acetic acid - the Applicant did not propose monitoring. We have included periodic monitoring for acetic acid as acetate is confirmed as a possible degradation product. This monitoring is consistent with other permits in the sector.

We have included the necessary monitoring requirements in table S3.1 of the Permit which are linked to the pre-operational condition.

Monitoring specified in table S3.1 is the minimum required of the Operator. If suitable CEMS become available, the Operator can apply to vary the monitoring to continuous in the future.

8.1.4 Monitoring location compliance

The Applicant confirmed that new sample locations pre and post carbon capture will be compliant with the requirements of our M1 Stack Monitoring Guidance, as far as reasonably practicable.

In their response to our Schedule 5 Notice for further information dated 16/07/2024 the following additional information was provided:

Monitoring locations for existing emission points A1, A3 and A4 can meet the required criteria, whereas monitoring locations for existing emission point A2 and new emission points A6 and A7 will require computational fluid dynamics (CFD) analysis to be undertaken in accordance with ISO 16911 to support the final selection of the sampling location.

We had concerns about monitoring locations A2, A6 and A7, although we considered A2 to be of lower risk compared to A6 and A7. We highlighted these concerns to the Applicant in our email sent 24/10/2024. The Applicant provided further information 07/11/2024 which addressed our concerns.

They confirmed that the LCP and PCC monitoring locations will meet the flow requirements of BS EN 15259 and that the PCC monitoring platforms will meet the BS EN 15259 standard.

In our email 07/11/2024 we confirmed that emission monitoring at A2 will require isokinetic testing unless it can be demonstrated there are no mist or water droplets present at the monitoring location. Therefore, BS EN 15259 flow criteria must be met at emission point A2, unless it can be demonstrated there are no mist or water droplets present at the monitoring location.

We therefore set a pre-operation condition requiring the following:

- how the monitoring locations will comply with the BS EN 15259 standard;
- results of the CFD modelling and analysis;
- platform designs; and
- a method to demonstrate whether there are mist or water droplets present at emission point A2.

We also set an improvement condition for the assessment of monitoring locations during commissioning, at emission points A2, A6 and A7 and the LCP compliance monitoring locations pre-PCC plants. These assessments can only be done once the plant is operational. They are required to determine whether the monitoring locations meet the requirements of BS EN 15259 and where necessary, to provide proposals for improvements to meet the requirements and for emission point A2, to determine whether the requirements of BS EN 15259 are applicable, in accordance with the pre-operational condition described above.

8.2 Emissions to water (W2)

The Applicant confirmed that the wastewaters discharged via emission point W2 will be uncontaminated, refer to section 5.6.1 of this document. As there will be controls in place which include oil/water separators, we have included daily visual inspection for oil and grease in table S3.2 of the Permit and consider that further monitoring is not required in this table.

Although monitoring at W2 is not required, we have included process monitoring for amines at the discharge from the amine drain in table S3.4 of the Permit. This is to ensure that the necessary controls are in place.

8.3 Carbon Capture Plant Performance

We have included process monitoring requirements in the Permit covering the operation of each PCC plant. The monitoring concentrates on ensuring that solvent quality is monitored and maintained to ensure that CO_2 capture rates are optimised and degradation products (e.g. amines, nitrosamines and nitramines) are minimised. Iron and stable salt build up in the solvent can give an indication of plant corrosion and can lead to amine solvent degradation which may affect carbon capture performance. We have therefore required the Operator to routinely monitor for a number of parameters in table S3.4 of the Permit, which include iron content, heat stable salts and colour changes in the amine solvent. Yellowing of amine solvents takes place as iron levels build up and as the solvent ages.

We have also set an improvement condition for solvent degradation which includes the assessment of solvent quality over 12 months of operation.

With regard to carbon capture efficiency, the purpose of a post combustion carbon capture plant is to maximise the capture of CO_2 emissions. Operators should aim to achieve a design CO_2 capture rate of at least 95%, although operationally this can vary, up or down. The Applicant has stated in their application that the PCC plants have been designed to capture 95% of the CO_2 in the flue gas from the GTs and auxiliary boilers.

In order to assess whether CO_2 capture is maximised, monitoring and reporting requirements have been included in the Permit. A Pre-operational condition requires the Operator to provide a methodology for approval to demonstrate the carbon capture efficiency of the plant. This approved methodology will then be used to measure carbon capture efficiency as required in table S3.4 of the Permit.

We have also included an improvement condition, requiring the Operator to provide a report on carbon capture efficiency under normal operations after 12 months of operation.

As well as under normal operating conditions, the Operator is also expected to maximise carbon capture during periods of start-up and shut-down. A pre-operational condition requires the Operator to include proposals in their PCC commissioning plan for other than normal operating conditions (OTNOC) to monitor carbon capture performance during these periods.

Table S4.2 of the Permit requires the Operator to report annually on the time the PCC plants are not available as this has the potential to impact carbon capture efficiency.

9. Environment Agency initiated changes

As well as the changes applied for by the Applicant, we have made some changes to the Permit as detailed in the table below:

Permit condition /table	**Justification**
Companies registered office address	Updated consistent with the address on ‘Companies house’ website.
Condition 2.3.2	Amended in accordance with current permit template.
Condition 2.3.9	Amended to refer to the correct improvement condition IC20 instead of IC21.
Condition 3.1.4	Added to reference table S3.3.
Conditions 3.1.1, 3.5.1, 3.5.4, 3.6.7	Tables S3.1 and S3.1a to which the conditions refer have changed as detailed below.
Condition 3.6.7	Updated in accordance with the current permit template.
Condition 4.2.2(d)	Amended to replace ‘apply’ with ‘applies’.
Condition 4.3.2	Updated in accordance with the current permit template.
Table S1.1	LCP188, auxiliary boilers (AB1 & AB2) description updated to reference Permit conditions 2.3.5 and 2.3.6 for gas oil usage.
Table S1.2	Amended date received for variations V003 and V004. Added Multi-fuel Firing Plan, following discharge of improvement condition IC18.
Table S1.3	Amended to confirm completion of improvement conditions IC18 to IC20. IC18 recorded on Compliance Assessment Report (CAR) reference BJ8022IZ/0377399, dated 10/11/2020.

	IC19 confirmed as completed, with an agreed date of 17/12/2020. IC20 confirmed as completed. Amended to add an improvement condition to implement an automatic shut off control system to the ROG supply to the site/boilers if the fuel sulphur content exceeds the limit/specification in table S2.1 of the Permit. Amended to add an improvement condition for black start operations.
Table S2.1	Added text to gas oil description to allow alternative equivalent fuel to be used with our agreement. ROG limit updated to confirm that it is the ‘hourly average limit’.
Table S3.1	Original table S3.1 deleted as this was relevant to emission limits and monitoring requirements that applied until 16 August 2021. Current table S3.1 is for CO_2 abated operation, with table S3.1a for CO_2 unabated operation.
Table S3.1a	Amended source for sulphur dioxide at emission point A2 from GT1/HRSG1 to GT2/HRSG2.
Tables S3.1 and S3.1a	Included notes to the tables, consistent with the current permit template to confirm when the limits apply (DLN and MSUL/MSDL to baseload).
Table S3.2	Amended NGR for emission point W1 from 51713 41701 to 517000, 417190. Included relevant monitoring methods and reference periods. This includes the requirement for the flow measurement at W1 to be MCERTs. Where the reference period is ‘instantaneous’, this means the limit is the maximum as it’s not averaged.
Schedule 5 - Notification	Updated in accordance with the current permit template.
Schedule 6 - Interpretation	Updated in accordance with the current permit template and to update the commissioning definition.
Schedule 7 – Site plan	Updated to include the copyright reference.

10. Additional updates/changes requested by the Applicant

Changes implemented to update the Permit **at the request of the Applicant 18/12/2024 and 20/02/2025**	
Tables S3.1 and S3.1a	**Point 1.0 – General** We have deleted original table S3.1, that applied until 16/08/2021, see section 9 of this document. This table was superseded by original table S3.1a, which applied from 17/08/2021.
Tables S3.1 and S3.1a	**Point 2.0 - A5 (LCP 415: GT3/HRSG3) – NOx** For multi fuel firing at emission point A5, we have replaced ‘Note 1’ with the natural gas limits which the Operator confirms they can comply with. Evidence was provided to support this in Compliance Assessment Report (CAR) form BJ8022IZ/0377399. It was agreed that the multi-fuel firing plan (MFFP) does not apply to emission point A5. We also updated Note 2.
Tables S3.1 and S3.1a	**Point 3.0 - A5 (LCP 415: GT3/HRSG3) – SO_2** We have removed SO_2 limits and associated continuous monitoring requirements at emission point A5. The Operator confirmed that: For emission point A5, SO_2 limits are specified when firing natural gas, refinery off gas (ROG) or multi-fuel. Limits were retained in the permit on the basis of the ‘no back-sliding’ principle. There is no available evidence demonstrating why limits were set in the first place. • The IED Annex V Part 1 (3) defines an SO_2 limit of 35 mg/nm^3 for combustion plants using gaseous fuels but states the limit does not apply to gas turbines. • The LCP BAT Conclusions do not specify a BAT-AEL for SO_2 for natural gas fired gas turbines. • The Refining of Mineral Oil and Gas BAT Conclusions defines a BAT-AEL range of 5 – 35 mg/nm^3 for SO_2 from combustion plants firing Refinery Fuel Gas (Table 13) but excludes gas turbines.

	The facility does not fall within the jurisdiction of a local authority with an Area Quality Management Area for SO_2. Monthly mean and maximum daily mean SO_2 emissions for A5 from January 2023 to January 2024 were provided. Monthly means ranged from 0.6 to 1.6 mg/m^3 with daily means ranging from 0.6 to 7.2 mg/m^3. Based on the Operator’s justification we are satisfied that the SO_2 limits and associated continuous monitoring are no longer required. Table S2.1 of the Permit limits the sulphur content of the ROG to 0.02% w/w. We have also added an improvement condition to table S1.3 of the Permit. This condition requires the Operator to review options to ensure that the ROG sulphur content does not exceed the limit set out in table S2.1 of the Permit. The review shall include consideration of an automatic shut-off control system for the ROG supply to the Installation.

Tables S3.1 and S3.1a	**Point 4.0 - A3 & A4 (LCP 188: AB1/2) – Distillate Fuel Firing ELVs** We have removed all limits for the auxiliary boilers when firing distillate fuel. This is relevant to emission points A3 and A4 (table S3.1a) and A6 or A7 (table S3.1). The Operator confirmed that distillate fuel oil is a back-up fuel in the auxiliary boilers and would only be fired in emergency scenarios when the supply of natural gas is interrupted and there is a need to maintain energy supplies. The LCP BAT Conclusions states: *“The BAT-AELs set out in these BAT conclusions may not apply to liquid-fuel-fired and gas-fired turbines and engines for emergency use operated less than 500 h/yr, when such emergency use is not compatible with meeting the BAT-AELs.”* Permit condition 2.3.5 limit the use of distillate fuel to <500 hours/year. Permit condition 2.3.6 limits the use of distillate fuel for periods of up to 10 days during times of interruption to the gas supply. Table S2.1 of the Permit limits the sulphur content of distillate fuel to 0.1% w/w.
Tables S3.1 and S3.1a	**Point 5.0 - A3 & A4 (LCP 188: AB1/2) – NOx** The Operator confirmed that the current permit defines monthly, daily and hourly NO_X limits when solely firing natural gas, ROG or distillate and refers to “Note 1” for multi-fuel firing. The note references the calculation of the dynamic multi-fuel weighted emissions limit values (DELV) according to the formulae provided in IED Article 40(2). As we have approved the MFFP submitted to close out IC18 (see CAR form BJ8022IZ/0377399) and the distillate emission limits are not applicable (as defined by the IED and LCP BAT conclusions). They request that the references to Note 1 are replaced by the agreed limit ranges for natural gas and ROG (co-combustion of natural gas and ROG is the only multi-fuel firing scenario in normal operation). We have included the relevant range in the table for the two fuels with a note that refers to multi-fuel firing.

Tables S3.1 and S3.1a	**Point 6.0 - A3 & A4 (LCP 188: AB1/2) – CO** We have amended the note to the tables to refer to 1,500 hours instead of 500 hours. LCP BAT 44 states: “As an indication, the yearly average CO emission levels will generally be: • < 5–40 mg/Nm^3 for existing boilers operated ≥ 1,500 h/yr”
Tables S3.1 and S3.1a	**Point 7.0 - A3 & A4 (LCP 188: AB1/2) – SO_2** We have removed emission limits and monitoring requirements for all parameters, refer to point 4.0 above. We have included the relevant range in the table for the two fuels instead of the note that refers to multi-fuel firing.

Annex 1 Decision checklist

Aspect considered	Decision
Receipt of application	
Confidential information	A claim for commercial or industrial confidentiality has not been made.
Identifying confidential information	We have not identified information provided as part of the Application that we consider to be confidential.
Consultation	
Consultation	The consultation requirements were identified in accordance with the Environmental Permitting Regulations (2016) and our public participation statement. The Application was publicised on the GOV.UK website. We consulted the following organisations (refer to section 2.2 of this document): • UK Health Security Agency (UKHSA) • The Director of Public Health • The Health and Safety Executive (HSE) • Food Standards Agency (FSA) • National Grid • North Lincolnshire Local Authority – Planning and Environmental Department The comments and our responses are summarised in the consultation section in Annex 2 of this document.
The facility	
The regulated facility	We considered the extent and nature of the facility at the site in accordance with RGN2 ‘Understanding the meaning of regulated facility’, Appendix 2 of RGN 2 ‘Defining the scope of the installation’, Appendix 1 of RGN 2 ‘Interpretation of Schedule 1’. The extent of the facility is defined in the site plan and in the permit. The activities are defined in table S1.1 of the Permit.

Aspect considered	Decision
The site	
Extent of the site of the facility	The Applicant has provided a plan which we consider is satisfactory, showing the extent of the site of the facility. The plan is included in the Permit.
Site condition report	See section 3.4 of this document.
Biodiversity, heritage, landscape and nature conservation	The Application is within the relevant distance criteria of a site of heritage, landscape or nature conservation, and/or protected species or habitat. See section 5.3 of this document for details of our assessment. We have assessed the Application and its potential to affect all known sites of nature conservation, landscape and heritage and/or protected species or habitats identified in the nature conservation screening report as part of the permitting process. We consider that the Application will not affect any sites of nature conservation, landscape and heritage, and/or protected species or habitats identified. We have consulted with Natural England, who agree with our conclusions.
Environmental risk assessment	
Environmental impact assessment	In determining the Application, we have considered the Environmental Statement.
Environmental risk	We have reviewed the Applicant's assessment of the environmental risk from the facility. Their risk assessment is satisfactory. See section 5 of this document for details of our assessment.
Operating techniques	
General operating techniques	We have reviewed the techniques used by the Applicant and compared these with the relevant guidance notes and we consider them to represent appropriate techniques for the facility. The operating techniques that the Applicant must use are specified in table S1.2 in the Permit.

Aspect considered	Decision
National Air Pollution Programme	
For applications involving emissions to air including ammonia, nitrogen oxides, non-methane volatile organic compounds, fine particulate matter or sulphur dioxide	We have considered the National Air Pollution Control Programme as required by the National Emissions Ceilings Regulations 2018. By setting emission limit values in line with technical guidance we are minimising emissions to air. This will aid the delivery of national air quality targets. We do not consider that we need to include any additional conditions in this Permit.
Permit conditions	
Pre-operational conditions	Based on the information in the Application, we consider that we need to impose pre-operational conditions. See table S1.4 of the Permit and the above sections of this document as summarised in the table below.

Ref.	Pre-operational measure
PO01	PCC plants Environment Management System (EMS) Refer to sections 3.5, 4.2 and 4.3.
PO02	PCC plants commissioning plan Refer to sections 6.1.1 (3.4.1 and 3.6.2 of the PCC plants BAT assessment) and 8.3.
PO03	PCC plants containment infrastructure Refer to section 3.4.
PO04	PCC plants drainage plan Refer to section 3.4.
PO05	PCC plants Noise Impact Assessment (NIA) and Noise Management Plan (NMP) Refer to section 5.6.4.
PO06	PCC plants CO_2 assessment Refer to sections 5.5 and 6.1.1 (3.5.1 of the PCC plants BAT assessment).

<table>
<tr><th>Aspect considered</th><th>Decision</th></tr>
<tr><td></td><td>
<table>
<tr><td>PO07</td><td><u>PCC plants process monitoring methods</u>
Refer to sections 6.1.1 (3.4.1 and 3.4.3 of the PCC plants BAT assessment) and 8.3.</td></tr>
<tr><td>PO08</td><td><u>PCC plants BAT for cooling options</u>
Refer to sections 6.1.1 (4.1 of the PCC plants BAT assessment) and 6.1.3.</td></tr>
<tr><td>PO09</td><td><u>Monitoring arrangements (A2, A6 and A7)</u>
Refer to section 8.1.4.</td></tr>
<tr><td>PO10</td><td><u>PCC plants other than normal operating conditions (OTNOC) plan</u>
Refer to sections 6.1.1 (3.6.2 of the PCC plants BAT assessment) and 8.3.</td></tr>
<tr><td>PO11</td><td><u>Emissions from storage of solvent</u>
Refer to sections 5.6.2, 5.6.3 and 6.1.1 (3.8.2 of the PCC plants BAT assessment).</td></tr>
</table>
</td></tr>
<tr><td>Improvement programme</td><td>Based on the information in the Application, we consider that we need to impose an improvement programme. See table S1.3 of the Permit and the above sections of this document as summarised in the table below.
<table>
<tr><th>Ref.</th><th>Improvement programme</th></tr>
<tr><td>IC21</td><td><u>PCC plants commissioning</u>
Refer to sections 4.2, 5.2.1c and 5.2.1e.</td></tr>
<tr><td>IC22</td><td><u>Monitoring locations (A2, A6, A7 and LCP compliance monitoring locations pre-PCC plants)</u>
Refer to sections 8.1.4 and 6.1.1 (3.4.2 of the PCC plants BAT assessment).</td></tr>
<tr><td>IC23</td><td><u>PCC plants carbon capture performance</u>
Refer to sections 6.1.1 (3.1.1 of the PCC plants BAT assessment) and 8.3.</td></tr>
<tr><td>IC24</td><td><u>PCC plants amine solvent degradation</u>
Refer to sections 6.1.1 (3.2.1 and 3.3.2.2 of the PCC plants BAT assessment) and 8.3.</td></tr>
<tr><td>IC25</td><td><u>Validation of PCC plants air emissions risk assessment</u></td></tr>
</table>
</td></tr>
</table>

<table>
<tr><th>Aspect considered</th><th>Decision</th></tr>
<tr><td></td><td>
<table>
<tr><td></td><td>Sections 5.2.1c and 5.2.1e.</td></tr>
<tr><td>IC26</td><td>PPC plants leak detection and repair (LDAR) programme
Refer to sections 6.1.1 (3.5.1 of the PCC plants BAT assessment)</td></tr>
<tr><td>IC27</td><td>ROG control system
Refer to section 10.</td></tr>
<tr><td>IC28</td><td>PCC plants monitoring at W2
Refer to section 5.6.1.</td></tr>
<tr><td>IC29</td><td>Black start operations
In the event of a black out, National Grid would call on combustion plant to operate and may require them to do so outside their permitted conditions. We have dedicated black start plant and they are permitted to run as such. This improvement condition is relevant to the LCP which could be called depending on the circumstances.
The improvement condition requires a risk assessment to be carried out. Air emissions modelling will be based on generic black start scenarios to establish whether they have the potential to have a local impact on the environment or not (on a national basis). If the modelling demonstrates that no significant impacts are likely, the plant can operate under Permit condition 2.3.9.</td></tr>
</table>
</td></tr>
<tr><td>Emission limits</td><td>Emission limits for emissions from the PCC plants have been set based on the Applicant’s predicted emissions which are considered to be BAT for this Installation in accordance with the PCC emerging techniques guidance, see section 7 of this document.</td></tr>
<tr><td>Monitoring</td><td>We have decided that monitoring should be added for the parameters detailed in tables S3.1 and S3.1a, using the methods detailed and to the frequencies specified in the permit.
These monitoring requirements have been imposed in order to meet requirements of Annex V of the IED and the AELs specified in the LCP BAT Conclusions document.
We have also included monitoring for a range of amines specifically for when the plant is operating in CO_2 abated mode.</td></tr>
</table>

Aspect considered	Decision
	We made these decisions in accordance with the SGN Combustion Activities (EPR1.01) and the monitoring methods are in accordance with our guidance at Monitoring stack emissions: environmental permits - GOV.UK (www.gov.uk) (formerly M2) and our PCC emerging techniques guidance. Based on the information in the Application we are satisfied that the Operator’s techniques, personnel and equipment have either MCERTS certification or MCERTS accreditation as appropriate.
Reporting	We have specified reporting in the Permit. The reporting requirements have been specified in order to comply with the requirements of the IED. We made these decisions in accordance with the *JEP Electricity Supply Industry – IED Compliance Protocol for Utility Boilers and Gas Turbines, dated November 2022* and our PCC emerging techniques guidance.
Operator competence	
Management system	There is no known reason to consider that the Operator will not have the management system to enable them to comply with the Permit conditions. The decision was taken in accordance with the guidance on operator competence and how to develop a management system for environmental permits.
Growth duty	
Section 108 Deregulation Act 2015 – Growth duty	We have considered our duty to have regard to the desirability of promoting economic growth set out in section 108(1) of the Deregulation Act 2015 and the guidance issued under section 110 of that Act in deciding whether to grant this permit. Paragraph 1.3 of the guidance says: “The primary role of regulators, in delivering regulation, is to achieve the regulatory outcomes for which they are responsible. For a number of regulators, these regulatory outcomes include an explicit reference to development or growth. The growth duty establishes economic growth as a factor that all specified regulators should have regard to, alongside the delivery of the protections set out in the relevant legislation.”

Aspect considered	Decision
	We have addressed the legislative requirements and environmental standards to be set for this operation in the body of the decision document above. The guidance is clear at paragraph 1.5 that the growth duty does not legitimise non-compliance and its purpose is not to achieve or pursue economic growth at the expense of necessary protections. We consider the requirements and standards we have set in this permit are reasonable and necessary to avoid a risk of an unacceptable level of pollution. This also promotes growth amongst legitimate operators because the standards applied to the operator are consistent across businesses in this sector and have been set to achieve the required legislative standards.

Annex 2 Consultation

Advertising and consultation on the Application

The following summarises the responses to consultation with other organisations, our notice on GOV.UK for the public and the way in which we have considered these in the determination process.

Responses from organisations listed in the consultation section:

Response received from
UK Health Security Agency (UKHSA), Environmental Public Health Scientist (12/04/2024)
Brief summary of issues raised and summary of actions taken
Incidents/accidents hazards and risks to public health 1. That the Application does not provide the Environmental Statement containing the Major Accident and Disaster assessment (appendix B) mentioned in the Application, particularly in light of potential flooding or any new storage requirements.
Summary of actions taken or show how this has been covered We don't consult on the Environmental Statement; this can be found on the Planning portal. For new storage requirements and flooding refer to sections 3.4 and 4.4 of this document.
Toxicology assessment
2. Degradation products (amide, formamide, acetonitrile, ethanol, acetone) That the Applicant notes a number of possible degradation products of the solvent, in Table A2 and A3 - while some of these are addressed in the Application, e.g. the nitrosamines, no further detail on the assessment of the amide and formamide, acetonitrile, ethanol and acetone degradation products is provided; we note the assessment of amides as acrylamide in table 2-3 of the main Appendix F document, but this decision lacks justification.
Summary of actions taken or show how this has been covered We sent a Schedule 5 Notice for further information (dated 16/07/2024) to the Applicant asking for the information highlighted below: i Provide a detailed justification for the use of the acrylamide Environmental Assessment Level (EAL) for the assessment of amides. *Notes: e.g. why the amides behave in a similar way to acrylamide, whether it represents equivalence or worst case etc.* ii Provide a justification for the exclusion of acetonitrile, ethanol and acetone from the assessment or include them in an updated assessment or addendum. iii Provide an amended assessment of impacts using the current long-term EAL for acrylamide of 0.05 µg/m^3, if acrylamide is justified to be an appropriate proxy, or propose an alternative assessment approach.

In their response to our Schedule 5 Notice the following evidence was provided:

i. Amides/acrylamide EAL

Appendix F of the Main Supporting Document stated that formamide 1 and 2, and amide 1 and 2 were confirmed degradation products. Total “Amides” were assessed at a concentration of 0.032 mg/Nm^3 against the EAL for acrylamide provided in the EA Risk Assessment Guidance at the time of the assessment (18 µg/m^3 as an hourly mean and 0.6 µg/m^3 as an annual mean), as the lowest EAL of any amide in the Guidance and the predicted impacts were <1% of the EALs applied and therefore considered insignificant.

Acrylamide is classified as a CMR (carcinogen, mutagen, reproductive toxicant) chemical, whereas the amides formed from the degradation of the CANSOLV amines are not considered to be CMR chemicals. It is therefore considered that the use of the acrylamide EAL in Appendix F is very conservative.

i Formamide

In terms of formamide specifically, the established carcinogenicity data in the registration dossier, which can be used as a read-across for formamide 1 (1-formyl-4-(2hydroxyethyl) piperazine), has a NOAEL of 20 mg/kg bw/day. The calculations from the Environment Agency’s "Derivation of new Environmental Assessment Levels (EALs) to air consultation" have been applied:

The oral route NOAEL needs to be converted to an inhalation route, assuming 70 kg and breathing at a rate of 20 m^3/day:

20 mg/kg bw/day = 70 mg/m^3

The recommended Uncertainty Factor (UFs) = 10 for inter-species, 10 for inter-individual, 10 for severity of effect are then applied:

Recommended long-term EAL for formamide = 0.07 mg/m^3 or 70 µg/m^3.

No short-term EAL is recommended due to its chronic (rather than acute) toxicity.

The expected maximum concentrations of formamides in the emission from the VPI PCC plants, as a 24-hour average is 0.001 mg/m^3. Given that the original assessment considered a total amide emission of 0.032 mg/Nm^3 insignificant against an EAL of 0.6 µg/m^3, it follows that an emission of 0.001 mg/m^3 would be insignificant against an EAL of 70 µg/m^3.

i Amide 1

Amide 1 it is predicted to cause respiratory irritation by the Resipratox QSAR (https://respiratox.item.fraunhofer.de/index.php) model.

Based on the Point of Departure (POD) (respiratory irritation), and considering the lack of data available, it is considered justifiable to read-across the EALs for MEA, which is considered to be conservative.

i Amide 2

There is also no data available for amide 2, however it is predicted to cause respiratory irritation by the Resipratox QSAR model.

Based on the POD (respiratory irritation), and considering the lack of data available, it is again justifiable to read-across to MEA for suitable EALs.

It is therefore considered that given the very low concentration of the release of amides from the VPI PPC plants, these would be considered insignificant against the MEA EAL.

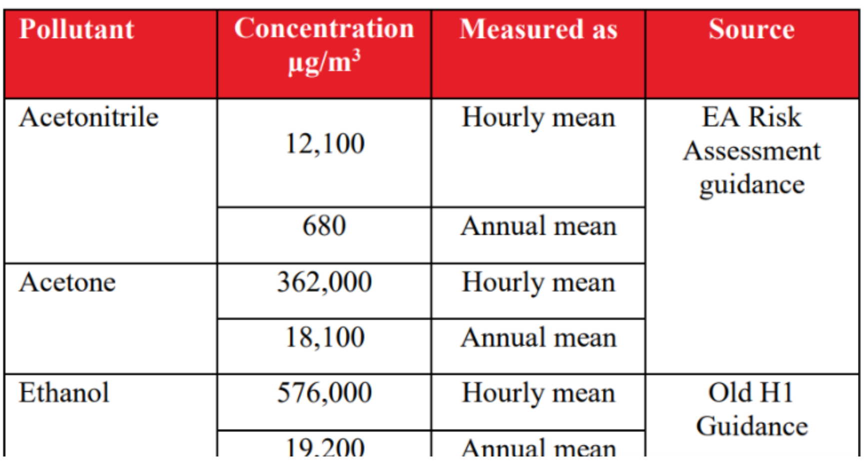
ii Acetonitrile, ethanol and acetone

Appendix F of the Main Supporting document stated that acetonitrile, ethanol and acetone were possible degradation products of CANSOLV DC-103, which had been picked up in some monitoring results, but were not considered to be linked to an established degradation pathway of the solvent.

The expected maximum concentrations of these substances as a 24-hour average based on monitoring data are very low levels:

- Acetonitrile - 0.17 mg/m^3
- Ethanol - 0.002 mg/m^3
- Acetone - 0.05 mg/m^3

They provided the EALs for acetonitrile, ethanol and acetone, noting that there is no current EAL for ethanol in our Risk Assessment Guidance and therefore the value that was provided in the previous H1 Guidance (now withdrawn) was referenced in the absence of a current EAL.



Pollutant	Concentration µg/m^3	Measured as	Source
Acetonitrile	12,100	Hourly mean	EA Risk Assessment guidance
	680	Annual mean	
Acetone	362,000	Hourly mean	
	18,100	Annual mean	
Ethanol	576,000	Hourly mean	Old H1 Guidance
	19,200	Annual mean	

An alternative EAL for ethanol, using the $BDML_{10}$ method used to derive NDMA EAL has also been considered. The $BDML_{10}$ of ethanol is 1,400 mg/kg. Converting this to mg/m^3, assuming 70 kg and 20m^3/day breathing rate is 4,900 mg/m^3.

The $BMDL_{10}$ of 4,900 mg/m^3, modelled from the Klein et al. (1991) (KLEIN R.G., JANOWSKY I., POOL-ZOBEL B.L., SCHEMZER P., HERMANN R., AMELUNG F., SPIEGELHALDER B., ZELLER W.J.,1991. Effects of long-term inhalation of N-nitrosodimethylamine in rats. IARC SCIENTIFIC PUBLICATIONS, 105, 322 – 328.) data, is adjusted for continuous exposure by multiplying by (4/7) days and (4/24) hours to give a final POD of 466.7 mg/m^3.

A long-term EAL of 0.047 mg/m^3 (or 47µg/m^3) is then obtained by dividing the POD by 10,000, which is considered to be a suitable margin of safety for minimal risk for a genotoxic carcinogen (COC 2018) (Appendix C: summary of toxicological evidence for MEA and NDMA - GOV.UK). This is significantly lower than the old H1 Guidance annual mean EAL for ethanol.

It can be seen that the acetonitrile and acetone EALs are comparatively high values compared to some of the EALs that were used in the original assessment (acetaldehyde for example, which has EALs of 9,200 µg/m^3 and 370 µg/m^3 for hourly and annual impacts respectively).

Modelling carried out to date assessed the impacts of acetaldehyde at an emission concentration of 0.2 mg/m^3, and the predicted impacts were less than 0.1% of both the hourly and annual EALs. It therefore follows that modelling of acetonitrile, ethanol and acetone at the maximum expected concentrations (all less than 0.2 mg/m^3) would also lead to impacts that are insignificant, especially considering the higher EALs that are associated with these species. Impacts of ethanol at a release concentration of 0.002 mg/m^3 would also be considered insignificant against the lower proposed EAL of 47 µg/m^3.

For acetonitrile, we note that the hourly mean is 10,200 µg/m^3; however this would not change conclusions.

iii Amended assessment of impacts using the current long-term EAL for acrylamide

As stated in response to point ii above, it is considered that EALs for the specific amide species would be higher than the EALs used in Appendix F of the Main Supporting Document, which assessed total amides at a concentration of 0.032 mg/Nm^3 against an EAL of 0.6 µg/m^3 (as an annual mean), with predicted impacts of 0.002 µg/m^3, or 0.3% of the EAL applied. It is therefore considered that the original assessment was very conservative.

If assessed against the revised annual average EAL of 0.05 µg/m^3 for acrylamide, the PC of 0.002 µg/m^3 would represent 3.8% of the EAL. As there is no information on available background levels of acrylamide, these are assumed to be 0 µg/m^3, and therefore the PEC would be well below the 70% threshold to demonstrate that the impacts are not significant.

As in the response to point i however, acrylamide is classified as a CMR (carcinogen, mutagen, reproductive toxicant) chemical, whereas the amides formed from the degradation of the CANSOLV amines are not defined as CMR chemicals. It is therefore considered that the use of the acrylamide EAL is very conservative, as justified in the response to point ii.

3. Amine 1 – proposed use of MEA EAL (irritancy effects) - For amine 1 (1-Piperazineethanol), the Applicant notes the low systemic toxicity and lack of alerts for carcinogenicity, mutagenicity and reproductive toxicity. It is a strong ocular and skin irritant. It is anticipated that the main effect will be local irritancy as is the case for monoethanolamine (MEA) for which there is a published EAL available. The Applicant considers that it is reasonable to assume that the EAL that protects for the local effects of MEA would also be protective for the local effects of amine 1. UK HSA does not consider that this is sufficient justification as no evidence is presented on the concentrations at which amine 1 causes irritancy effects.

Summary of actions taken or show how this has been covered

We sent a Schedule 5 Notice for further information (dated 16/07/2024) to the Applicant asking for the information highlighted below:

Provide evidence/data to show at what concentrations amine 1 and mono-ethanolamine (MEA) cause irritancy effects and justify why the MEA EAL is applicable.

In their response to our Schedule 5 Notice the following evidence was provided:

There is only one study available for Amine 1 using the inhalation route, which was a non-GLP acute inhalation study with saturated vapour (concentration not determined) following a protocol similar to OECD 403 (BASF, 1967, (summary available in the ECHA registration dossier) (ECHA CHEM). Six rats per sex were exposed for 8 hours to vapours generated by bubbling 200 l/h of air through a substance column.

Clinical signs were documented over a period of 8 days. No mortality was observed, one animal showed chronic bronchitis and bronchiectasis in the right lobe of the lung. To verify the results, the test was repeated once with new groups of animals. In summary, no clinical signs were observed that would indicate any irritation or other systemic effects occurred post exposure to Amine 1 vapours.

A set of Adverse Outcome Pathway (AOP) New Approach Methodologies (NAMs) were conducted to assess whether Amine 1 is a sensitiser. These assays show definitive evidence that Amine 1 is not a sensitiser. Results of the Direct Peptide Reactivity Assay (DPRA) (OECD442C and D) and LuSENS (The LuSens assay uses a luciferase reporter cell line (LuSens cells) based on the activation of the antioxidant response element that can be used to assess the intracellular cysteine reactivity of a substance.) assays show that Amine 1 is not peptide reactive and does not activate keratinocytes in vitro and thus is not predicted to be a skin sensitiser.

Finally, data is available for skin and eye irritation for Amine 1, which concludes that Amine 1 is non-irritating to skin, but it is category 1 irritating to eyes.

Modelling of respiratory effects

The RespiraTox project developed a QSAR model for identifying potential human respiratory irritants using a novel in silico strategy. Using the RespiraTox modelling software for respiratory irritation and tissue damage the model returned the following results for MEA, Amine 1, and Amine 3: for Amine 1 the database was able to run models against available data in the ECHA database for acute tox and used the existing data for Amine 1 to model.

Both Amine 1 and Amine 3 returned positive irritation predictions at high confidence levels, $p=0.96$ and $p=0.87$, respectively. For MEA due to data availability for the specific end point, MEA has a confidence level of $p=1$. It is to be noted that Amine 1 in the RespiraTox database is classified as a non-irritant (based on available data in the ECHA chemical database), however, RespiraTox is programmed to return a worst-case scenario where positive neighbouring substances are available. Such as in the case of Amine 1, where the compound itself is classified as non-irritating but with the additional evidence of similar compounds it is designated as irritant by the program. This does not change Shell’s position, as we are using the irritation of MEA as the POD.

The model returned a 77% similarity between Amine 1 and MEA, while Amine 1 and Amine 3 share 85% similarity. This similarity coupled with the shared end point of respiratory irritation as a point of departure for EAL calculation supports the proposal of using MEA as the read across for both Amine 1 and Amine 3.

Annex A of Appendix F provided supporting toxicological information for the amines found in CANSOLV DC-103. The supporting information for Amine 1 included a table of results of QSAR modelling to support the conclusion that MEA was a suitable read-across. The table has been updated with the specific end points for MEA, to facilitate this comparison.

From the data they present they confirm that there is no end point where Amine 1 is a greater hazard in comparison to MEA and that QSAR modelling predicts that Amine 1 will have respiratory irritation as a common end point with MEA.

Amine 1 is not a respiratory sensitiser (contrary to piperazine) and therefore it is considered that MEA is a more appropriate read-across.

That said however, even if the predicted impacts of Amine 1 and 3 were compared to the proposed lower EAL for piperazine of 0.015 mg/m^3 (averaged over 24-hours) the predicted maximum PC of 0.1 µg/m^3 would represent 0.8% of the EAL and therefore would still be considered insignificant.

4. Amine 1 vapour pressure - The Applicant notes differences in vapour pressure between amine 1 and MEA, such that exposures are below the MEA EAL. It is not clear to the General Toxicology and Biomonitoring Programme at UKHSA to what extent vapour pressure would be considered in the dispersion modelling approach, such that there could be double counting if it is also considered in determining an appropriate proxy EAL value.

Summary of actions taken or show how this has been covered

We also disagree with this approach of comparing the differences in vapour pressure between amine 1 and MEA to conclude that exposures are below the MEA EAL. The vapour pressure plays a role in determining the emission rate from a process, hence it has impacts on the resulting process contributions at receptors, but is not relevant to the toxicological properties and effects of a given substance.

5. Amine 1 proposed use of MEA EAL (NOAEL) - The Applicant's anticipation that a systemic NOAEL for amine 1 would likely be higher than the systemic NOAEL for MEA. UK HSA has not considered the basis of the systemic NOAEL for MEA, as no reference is provided for this in the Application, and considers that as the MEA EAL is not based on systemic effects, it is unclear how a justification on potency with respect to systemic effects would necessarily ensure appropriate health protection.

Summary of actions taken or show how this has been covered

We questioned the use of the NOAEL for MEA: The long-term EAL for MEA is based on local irritancy effects, not systemic effects.

We note that page 53 of appendix D to the Application states 'To date, a NOAEL has not been derived for Amine 1, however based on structural similarity with Amine 2 and Amine 3, Amine 1 is expected to have a systemic NOAEL of the same order of magnitude.

It is difficult for us to understand where the comparison of systemic toxicity has come from with amine 1. Since amine 1 is a piperazine structural analogue, we required further justification as to why MEA is a more suitable comparator than the evidence for systemic toxicity for piperazine and the latter compounds potential to form nitrosamines within the body following inhalation exposure.

We would expect consideration of whether piperazine might provide a more suitable read-across case for Amine 1, given that it consists of a piperazine structural analogue, hence it might present closer structural similarity with piperazine. If this is the case consideration of the long-term EAL recently approved by the UKHSA for piperazine of 0.015 mg/m^3 (averaged over 24-hours to protect public health) will also be required including a potential re-assessment of impacts. This piperazine long-term EAL has since been published following public consultation (Environmental Assessment Levels for the amine-based carbon capture process - GOV.UK).

We sent a Schedule 5 Notice for further information (dated 16/07/2024) to the Applicant asking for the information highlighted below:

Provide further detailed justification to support the approach taken in concluding that the NOAEL for amine 1 would be higher that the NOAEL for MEA or justification to support an alternative approach. The justification should take account of the possibility for in-vivo transformation of the piperazine structural analogue in the body via inhalation exposure.

In their response to our Schedule 5 Notice the following evidence was provided:

The response provided for item 3 above provides evidence to support the use of the MEA EAL for Amine 1, and also demonstrates that predicted impacts would still be insignificant if the proposed lower EAL for piperazine were used in the assessment.

The CANSOLV amines are structural analogues, consisting of a heterocyclic di-amine (Amine 2), with an alkanol group substitution on one (Amine 1) or both (Amine 3) amine functions.

Amine 1 has low vapour pressure and is a strong ocular and skin irritant.

Amine 2 has low vapour pressure and is a strong ocular and skin irritant. It is classified for respiratory sensitisation and reproductive toxicity.

Amine 3 is a minor component of the DC-103 solvent with low volatility and is generally not detected in emissions. It has a low vapour pressure and is a strong ocular and skin irritant.

Due to their common active group (the amine group), the overall toxicity of all aliphatic amines is similar, with some potency differences depending on the aliphatic parts. Based on a review of the toxicological properties of alkanol-amines, cyclic amines, and aliphatic amines, supplemented with modelling of the structure-activity relationship, the following can be summarised regarding the toxicity of these compounds in the human body:

- Amines are metabolised by oxidation into the corresponding aldehydes, a process accompanied by the release of ammonia. The aldehydes are then metabolised into carboxylic acids and, ultimately, into CO_2 (that is subsequently exhaled).
- Aliphatic amines and alkanolamines are of relatively low acute toxicity, with LD50 levels (Lethal Dose for 50% of the test animals) in the order of grams per kilogram bodyweight. The cyclic amines have a lower threshold of toxicity (LD50 levels in the order of 100s of milligrams per kilogram bodyweight) but are still of relatively low acute toxicity.
- Except for tertiary amines, the range of aliphatic amines, alkanolamines, as well as cyclic amines are to some degree corrosive or highly irritating to the skin, eyes and/or respiratory tract.
- Except for piperazine, amines are not skin nor respiratory sensitisers.
- Overall, amines are not mutagenic or carcinogenic and, with exception of piperazine, amines are not expected to affect human development or reproduction.
- Overall, amines will pose minimal risk to members of the public. However, due to their corrosive properties risk management measures need to be in place for workers.
- The main amine present in the emission is Amine 1. Based on available data, as well as modelling data, all CANSOLV DC-103 amines are expected to be of low systemic toxicity with no alerts for carcinogenicity, mutagenicity, or reproductive toxicity.

Based on the results of the DPRA and LuSENS assays, Amine 1 is not peptide reactive and does not activate keratinocytes in vitro. These results are supported by the results of a Guinea Pig Maximisation Test according to Magnusson that demonstrate that the substance does not meet criteria for classification and is therefore not classified as a skin sensitiser in vivo. This addresses the concern of Amine 1 and Amine 3 exposure leading to piperazine exposure via “in-vivo transformation”.

Based on the above therefore, it is considered that the NOAEL for amine 1 would be higher than the NOAEL for MEA.

6. **Amine 2 (piperazine) short and long-term values** - For amine 2 (Piperazine), the Applicant proposes short- and long-term values based on the worker (rather than general population) short- and long-term Derived No Effect Levels (DNELs) for respiratory sensitisation. It is unclear to UKHSA how this worker DNEL has been derived, i.e. what study it is based on and the uncertainty factors applied. For the long-term value, the Applicant has applied a time adjustment from 8 hours to 24 hours and a 40-year working life span to an 80-year life-time exposure. For the short-term value the 15-minute worker value is adjusted to a 1-hour value. UKHSA notes that no comment or justification has been made of any consideration for the potential need for an additional uncertainty factor with respect to sensitivity of the general population for this effect.

Summary of actions taken or show how this has been covered

Since these comments were made, progress has been made with our derivation of a long-term EAL for piperazine. Working with the UKHSA, we have proposed a long-term EAL for piperazine of 0.015 mg/m^3 (15 ug/m^3) averaged over 24-hours to protect public health. This value is considered by us to be protective of other toxic effects including from short-term exposure and potential carcinogenicity resulting from in vivo conversion of piperazine to N-nitrosopiperazine following inhalation.

Following public consultation, we have published the EAL for piperazine (Environmental Assessment Levels for the amine-based carbon capture process - GOV.UK).

Our derived EAL for piperazine of 15 ug/m^3 is not that dissimilar from the one proposed for amine 2 (piperazine) of 17 ug/m^3, although the methodology and the explanation given were not as thorough as the evidence gathered and methodology used in our dossier.

On this basis, we have decided that we do not need to ask for any additional information or clarification in relation to amine 2 (piperazine), as it would be immaterial to our permitting decision as comparison of the amine 2 PC to this lower EAL is still well below the 1% significance criteria (see section 5.2 of this document), based on our derived long-term EAL for piperazine.

7. **Amine 2 (piperazine) NOAEL** – That the Applicant considers that the systemic NOAEL for amine 2 is higher than the systemic NOAEL for MEA. UKHSA has not considered the basis of the systemic NOAEL for MEA, as no reference is provided for this in the application, and considers that as the MEA EAL is not based on systemic effects, it is unclear how a justification on potency with respect to systemic effects would necessarily ensure appropriate health protection.

Summary of actions taken or show how this has been covered

Refer to comment for item 6 above.

8. **Secondary amines forming nitrosamines** - That there is uncertainty over the potential for secondary amines to form nitrosamines in the body, though there is some evidence for this from inhalation studies on piperazine.

Summary of actions taken or show how this has been covered

We agree there is uncertainty; however we are asking the Applicant to take into account the possibility for in-vivo transformation of the piperazine structural analogue for amine 1 in the body via inhalation exposure (item 5 above).

9. Amine 3 proposed use of MEA EAL (irritancy effects) - For amine 3 (1,4-Piperazinediethanol) the Applicant notes it is a strong ocular and skin irritant. It is anticipated that the main effect will be local irritancy as is the case for monoethanolamine (MEA) for which there is a published EAL available. The Applicant considers that it is reasonable to assume that the EAL that protects for the local effects of MEA would also be protective for the local effects of Amine 3. UK HSA does not consider that this is sufficient justification as no evidence is presented on the concentrations at which amine 3 causes irritancy effects.

Summary of actions taken or show how this has been covered

We sent a Schedule 5 Notice for further information (dated 16/07/2024) to the Applicant asking for the information highlighted below:

Provide evidence/data to show at what concentrations amine 3 and MEA cause irritancy effects and justify why the MEA EAL is applicable.

In their response to our Schedule 5 Notice the following evidence was provided:

Supporting evidence for Amine 3 is provided together with the evidence for Amine 1 in item 3 above.

10. Amine 3 proposed use of MEA EAL (NOAEL) - That the Applicant consider that the systemic NOAEL for amine 3 is higher than the systemic NOAEL for MEA. UKHSA has not considered the basis of the systemic NOAEL for MEA, as no reference is provided for this in the Application, and considers that as the MEA EAL is not based on systemic effects, it is unclear how a justification on potency with respect to systemic effects would necessarily ensure appropriate health protection for the general population.

Summary of actions taken or show how this has been covered

The long-term EAL for MEA is based on local irritancy effects, not systemic effects, therefore we question the use of the NOAEL for MEA.

It is difficult for us to understand where the comparison of systemic toxicity has come from with amine 2. Since amine 2 is piperazine, we require further justification as to why MEA is a more suitable comparator given the available evidence for systemic toxicity for piperazine (via the oral route) and its potential to form nitrosamines within the body following inhalation exposure.

The long-term EAL for MEA is based on local irritancy effects, not systemic effects, therefore we question the use of the NOAEL for MEA.

It is difficult for us to understand where the comparison of systemic toxicity has come from with amine 3. Since amine 3 is a piperazine structural analogue, we require further justification as to why MEA is a suitable comparator given the available evidence for systemic toxicity for piperazine (via the oral route) and its potential to form nitrosamines within the body following inhalation exposure.

In responding to this question, we would expect consideration of whether piperazine might provide a more suitable read-across case for Amine 3, given that it consists of a piperazine structural analogue, hence it might present closer structural similarity with piperazine. If this is the case consideration of the long-term EAL recently approved by the UKHSA for piperazine of 0.015 mg/m^3 (averaged over 24-hours to protect public health) will also be required including a potential re-assessment of impacts. This piperazine long-term EAL has since been published following public consultation (Environmental Assessment Levels for the amine-based carbon capture process - GOV.UK).

We sent a Schedule 5 Notice for further information (dated 16/07/2024) to the Applicant asking for the information highlighted below:

Provide further detailed justification to support the approach taken in concluding that the NOAEL for amine 3 would be higher than the NOAEL for MEA or justification to support an alternative approach. The justification should take account of the possibility for in-vivo transformation of the piperazine structural analogue in the body via inhalation exposure.

In their response to our Schedule 5 Notice the following evidence was provided:

Supporting evidence for Amine 3 is provided together with the evidence for Amine 1 in Point 5 above.

11. Nitrosamines of amine 1 and amine 2 - For the nitrosamines of amine 1 and amine 2, the Applicant has proposed to use the EAL for NDMA as the Environment Agency states that “NDMA is one of the most potent nitrosamines [in terms of carcinogenic potential]” and also one of the most studied N-amines. UKHSA is aware of the lack of data for many nitrosamines and the likely need to utilise a proxy.

Summary of actions taken or show how this has been covered

No action required, we accept the use of NDMA as a proxy as it is one of the highest potency n-amines for all exposure routes.

12. Amine 2 Buist et al paper - The Applicant has used information from the Buist et al paper, to illustrate that the potency of the nitrosamine of amine 2 is less potent than NDMA. UKHSA notes that this is based on oral data rather than inhalation data, which for NDMA was used as the basis for the EAL.

Summary of actions taken or show how this has been covered

No action required, in the absence of other published values for N-amines, and in order to ensure a conservative assessment, the Applicant has applied the EAL for NDMA to all N-amines (generated from amine 1 and amine 2) in the assessment. Refer to section 5 of this document.

13. Nitrosamines of amine 1 and amine 2 Plewa et al paper - The Applicant has used information from Plewa et al (2013) to demonstrate mutagenic potency of the nitrosamines of amine 1 and amine 2 compared to NDMA. UKHSA notes that the data in the paragraph and Table A6 appear to be conflicting as to which of the two nitrosamines is least potent. UKHSA has been unable to identify the Plewa et al reference, and notes that the Ames test would conventionally be used to determine whether or not a compound is genotoxic, not to explore potency. In the absence of information from the Plewa et al paper, UKHSA is not in a position to take a view on whether this would provide sufficient evidence to support the Applicant’s proposal that the nitrosamines for amine 1 and amine 2 are of lower potency than NDMA.

Summary of actions taken or show how this has been covered

We sent an email to the UKHSA 02/05/2024 confirming that the Plewa et al reference report was included with the consultation documents at Toxicological Documents.pdf (environment-agency.gov.uk). We asked them to confirm if this covered the necessary requirements and, if this was the case, to amend the above response accordingly, or otherwise to let us know what additional information we needed to request from the Applicant. The UKHSA did not respond.

Also refer to comment for item 12 above.

14. Amides - The Applicant has predicted exposures to amides from the process. No further details are provided on what amides may occur, beyond that in Annex A of Appendix F, so there is uncertainty in the validity of the Applicant's proposal to use acrylamide as a proxy for these compounds. In addition, UK HSA notes that the short- and long-term EAL values provided for acrylamide, does not match with the current long-term EAL for acrylamide of 0.05 µg/m^3 (annual mean) published in 2021. This will impact on the subsequent assessment of the maximum impacts presented in the report Table 6-6.

Summary of actions taken or show how this has been covered

We sent a Schedule 5 Notice for further information (dated 16/07/2024) to the Applicant asking for the information highlighted below:

Provide an amended assessment of impacts using the current long-term EAL for acrylamide of 0.05 µg/m^3, if acrylamide is justified to be an appropriate proxy, or propose an alternative assessment approach.

In their response to our Schedule 5 Notice the following evidence was provided:

It is considered that EALs for the specific amide species would be higher than the EALs used in Appendix F of the Main Supporting Document, which assessed total amides at a concentration of 0.032 mg/Nm^3 against an EAL of 0.6 µg/m^3 (as an annual mean), with predicted impacts of 0.002 µg/m^3, or 0.3% of the EAL applied. It is therefore considered that the original assessment was very conservative.

If assessed against the revised annual average EAL of 0.05 µg/m^3 for acrylamide, the PC of 0.002 µg/m^3 would represent 4% of the EAL. As there is no information on available background levels of acrylamide, these are assumed to be 0 µg/m^3, and therefore the PEC would be well below the 70% threshold to demonstrate that the impacts are not significant.

Acrylamide is classified as a CMR chemical, whereas the amides formed from the degradation of the CANSOLV amines are not defined as CMR chemicals. It is therefore considered that the use of the acrylamide EAL is very conservative.

Also refer to item 2 above.

Additional considerations

15. Amine 1 further studies - The Applicant's intention to conduct further studies on amine 1 is noted. The Environment Agency may wish to consider how to ensure that the results from these studies are considered prior to any operation of the carbon capture plant at this site.

Summary of actions taken or show how this has been covered

We are satisfied with the information provided and the conservative nature of the assessments.

16. Piperazine EAL - That piperazine is one of the amine compounds being considered by the Environment Agency for a formal EAL. The Environment Agency may wish to consider how EAL values published relevant to carbon capture and storage are incorporated in permits and variations such as this one.

Summary of actions taken or show how this has been covered

We have shared the proposed piperazine long-term EAL with the Applicant as part of the Schedule 5 Notice for further information dated 16/07/2024, refer to items 6 and 7 above. We provided a caveat that said that it could change as a result of the public consultation process.

17. Atmospheric N-amines - That the Applicant reports that there is over-prediction of the likely process contribution of N-amines, by formation in the atmosphere after release, at the receptors. The Environment Agency will be best placed to consider whether this is the case.

Summary of actions taken or show how this has been covered

We note the conservative nature of the Applicant's estimation and consider their conclusions for human health can be used for permit determination. For the assessment of N-amines, refer to section 5.2.1d of this document.

18. Assessment of nitrosamine from amine 3 - That the Applicant reports that as a tertiary amine, amine 3 does not form stable nitrosamines, and in addition amine 3 is only in minute quantities, and not always present, in the emissions. Therefore, no assessment of nitrosamine from amine 3 has been undertaken. The Environment Agency will be best placed to consider whether these reasons are justifiable, and thus whether it is appropriate to not assess nitrosamines from Amine 3.

Summary of actions taken or show how this has been covered

Amine 1 and amine 2 are secondary amines and can potentially form stable nitrosamines and nitramines (N-amines). The Applicant states that there is no nitrosamine associated with amine 3 as it "is a tertiary amine that does not form stable nitrosamines". We note that tertiary amine groups do not have any nitrogen-bound hydrogens available for abstraction, however, available publications [Note 1] at the time of our audit indicate that a nitrosamine forming reaction occurs via a different mechanism, yet there is limited published data for tertiary amine reaction constants. Given the low proportion of amine 3 released from the stack, we accept the Applicant's approach.

Note 1: "In tertiary amines the initial hydrogen abstraction can only take place from the alkyl chain, and subsequent formation of nitrosamines and nitramines necessitate C–N bond scission." Nielsen, C.J., Herrmann, H. and Weller, C. (2012). Atmospheric chemistry and environmental impact of the use of amines in carbon capture and storage (CCS). Chemical Society Reviews, 41(19), p.6684.
doi:https://doi.org/10.1039/c2cs35059a

19. Nitrosamines and nitramines from amine 1 and amine 2 - The estimates for process contributions from nitrosamines and nitramines formed from amine 1 and amine 2 are close to the EAL for NDMA, used as a proxy for evaluation of these exposures, at a number of the identified human receptors. As the predicted total nitrosamine and nitramine exposures are below the NDMA EAL value, so there is unlikely to be concern for health. The Environment Agency should ensure that the modelling undertaken to make the estimates are appropriate. Additionally, it would be prudent to ensure consideration of whether there are other nearby installations or proposed or future installations that would also result in nitrosamine emissions or formation in the atmosphere to ensure appropriate health protection in the local community.

Summary of actions taken or show how this has been covered

We note the conservative nature of the Applicant's estimation and consider their conclusions for human health can be used for permit determination.

As required by our guidance at Environmental permitting: air dispersion modelling reports - GOV.UK (www.gov.uk), the Predicted Environmental Concentration (PEC) should also take into consideration the likely future background concentration of nitrosamines as a result of planned sites, i.e. taking into account the proximity of other carbon capture schemes in the area, including the Phillips 66 and potentially other industrial establishments that will need to implement carbon capture schemes in order to achieve the UK decarbonisation targets.

We sent a Schedule 5 Notice for further information (dated 16/07/2024) to the Applicant asking for the information highlighted below:

Provide a cumulative assessment of emissions of nitrosamines, taking into account the nearby proposed Phillips 66 carbon capture project and, if possible, other carbon capture projects planned in the area.

In their response to our Schedule 5 Notice, the Applicant provided an updated N-amine assessment. The estimated PC of nitrosamines emitted by the PCC plant is not insignificant when compared to the NDMA EAL, accounting for up to 77% (previously 97.5%) of the EAL for NDMA at the worst affected receptor (due to be demolished).

Our assessment of this is provided in section 5.2.1d of this document.

In the comments received from the UKHSA, Environmental Public Health Scientist (12/04/2024, see above) they asked that any information arising from their recommendations be sent to them for consideration.

Based on the toxicology recommendations above, we sent the further information provided by the Applicant in response to our Schedule 5 Notice for further information dated 16/07/2024. This information was sent 06/11/2024.

On sending this information, we also asked for the UKHSA's view on whether piperazine might be considered a reasonable read across/proxy for amine 1 and amine 3 (see table below copied from the Applicant's air quality assessment) due to the structural similarities. We stated that if the UKHSA agree that piperazine is a suitable read across/proxy for these amines, we would be satisfied that no further information would be required regarding suitable EALs.

We also confirmed that for amine 1 and amine 3, the Applicant had compared the PC against the proposed EAL for piperazine (0.015 mg/m^3 - averaged over 24 hours) developed by us in consultation with UKHSA toxicologists. The impacts from amine 1 and amine 3 screen out as insignificant at <1% of the piperazine EAL.

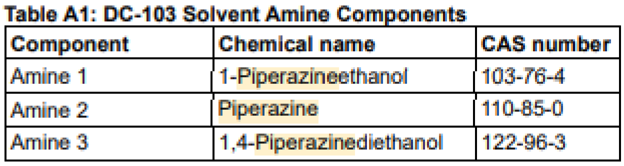


Table A1: DC-103 Solvent Amine Components

Component	Chemical name	CAS number
Amine 1	1-Piperazineethanol	103-76-4
Amine 2	Piperazine	110-85-0
Amine 3	1,4-Piperazinediethanol	122-96-3

Response received from
UK Health Security Agency (UKHSA), Environmental Public Health Scientists (12/02/2025)

Brief summary of issues raised and summary of actions taken

Amines

As the predicted maximum concentration for the sum of amine 1, amine 2 and amine 3 is over 100-fold below the proposed EAL for piperazine (Amine 2) of 15 µg/m^3, then these amine compounds are unlikely to present a risk to health.

Summary of actions taken or show how this has been covered

No action required.

In their schedule 5 response, the Applicant confirmed that even if the predicted impacts of amine 1 and 3 were compared to the proposed lower EAL for piperazine of 0.015 mg/m^3 (averaged over 24-hours) the predicted maximum PC of 0.1 µg/m^3 would represent 0.67% of the EAL and therefore would still be considered insignificant.

	Future – maximum at a human health receptor					
Pollutant	EQS/EAL (µg/m^3)	PC (µg/m^3)	PC as % of EQS/EAL	PEC (µg/m^3) (Background + PC)	PEC as % of EAL	Change in PC over baseline %
Amine 1 and 3 24 hour mean	15 [Note 1]	0.1	0.67	-	-	+0.67
Amine 1 and 3 Hourly mean	400	0.3	0.1	-	-	+0.1
Amine 2 (Piperazine) 24 hour mean	15 [Note 1]	0.01	0.07	-	-	+0.07
Amine 2 Hourly mean	75	0.03	0.04	-	-	+0.04
Amine 1 + amine 2 + amine 3 24 hour mean	15 [Note 1]	0.1 + 0.01 = 0.11	0.73	-	-	+0.73

Note 1: If we apply the much lower EAL for piperazine, the emissions still screen out as insignificant at <1% of the EAL.

Summing the PC of amine 1 and 3 (0.1 µg/m^3) with amine 2 (0.01 µg/m^3) would represent 0.73% of the piperazine EAL (averaged over 24-hours) and therefore would still be considered insignificant.

Nitrosamines and nitramines (amine degradation products)

Although there is some uncertainty, if the sum of the predicted concentration for total nitrosamines and nitramines is below the long-term EAL for NDMA, then this suggests a minimal risk to health.

They recommend that we consider whether total cumulative concentrations of N-amines arising from more than one nearby source has been sufficiently predicted, and that we consider this for future applications in the local area.

Summary of actions taken or show how this has been covered

The sum of the predicted concentration for total nitrosamines and nitramines is below the long-term EAL for NDMA, refer to section 5.2.1d of this document.

Regarding the N-amines cumulative assessment, we are satisfied that it is sufficient to consider just VPI and Phillips 66, refer to section 5.2.1e of this document.

Amides and formamide (amides)

They cannot currently comment on whether the amide and formamide compounds could present a risk to health without predicted maximum concentrations for all these identified degradation products and due to a lack of clarity on the proposed read-across approach.

Summary of actions taken or show how this has been covered

In their response to our request for further information, the Applicant confirmed that formamide 1 and 2, and amide 1 and 2 were confirmed degradation products. These were assessed as total "Amides" in the original assessment at a concentration of 0.032mg/Nm^3.

Refer to section 5.2.1b of this document for the detailed amide assessment and our conclusions.

Acetonitrile, acetone and ethanol

If we are content with the assumptions used to predict the concentrations for acetonitrile, acetone and ethanol, then these do not indicate a risk to health.

Summary of actions taken or show how this has been covered

We have set limits in table S3.1 of the Permit consistent with those used to assess impacts in the response to our Schedule 5 Notice for further information dated 16/07/2024. Refer to section 7 of this document.

Response received from

Natural England (14/06/2024)

Brief summary of issues raised

They agreed with our conclusions that the proposal will not result in adverse effects on the integrity of the sites in question. However, they did not consider the in-combination assessment to be complete as it only focused on other permit applications. They advised that there may be other plans or projects which may act in-combination with the permitted activity.

They then concluded that the Application is unlikely to cause significant damage to the Humber Estuary SSSI or result in a likely significant effect to the Humber Estuary SAC, SPA or Ramsar sites alone or in-combination with other plans and projects.

Summary of actions taken or show how this has been covered

We updated our HRA1 and HRA2 assessments to include other plans and projects. The assessments are available on our public register.

Responses from members of the public and community organisations

Brief summary of issues raised:	**Summary of action taken / how this has been covered**
Comments about environmental regulatory requirements, technical standards, technology	
Solvent selection Concern about failure to follow guidance for solvent selection: No relevant testing is reported, all performance data supplied is unsubstantiated, with no meaningful supporting evidence supplied. Numerous concerns raised about solvent choice. Concerned that no conclusive evidence has been presented in this Application that the combination of amine and plant design is the best that could be done or that it will give satisfactory long-term performance. Would expect an evaluation of different amines with some quantitative comparison and discussion of other factors such as toxicity to justify amine selection. An assessment process using evidence from realistic tests (i.e. over a long enough period of 12 months or more, with a realistic flue gas and with realistic solvent and emissions management in place). A key factor in this assessment is to demonstrate a reclaiming or cleaning process able to maintain a stable working solvent composition indefinitely. That there is no contractual barrier to using alternative solvents.	Refer to section 6.1.1 of this document for the BAT requirements associated with the carbon capture plants, specifically solvent selection in section 4.1 of the table, ‘Meeting the requirements for Post-Combustion Carbon Capture’. Regarding contractual barriers to the solvent used, our assessment of the Application is based on the proposed solvent. Any changes to this solvent would require the Operator to submit an Application to vary the Permit, which would be assessed on its own merits.

Absorber emissions abatement **Water wash and acid wash** The Application states that only a water wash is to be fitted. This will not give as great a reduction as possible in amine emissions as an acid wash and will not control ammonia emissions at all, unless used in conjunction with some other means of removing ammonia (and other volatile species) from the amine capture system, but no such additional means are described. An additional acid wash would offer improved performance in both respects. The Application states, incorrectly, (Appendix F, Section 1-3) that “The low amounts of lighter products, in particular ammonia, are also well controlled with this water wash system and usually do not mandate the addition of an acid wash stage.” This statement is incorrect because without a means of disposing of volatile species produced in the system they will build up to a level where they will exit the water wash at the rate they are formed or added, as noted in the Guidance “Water washes alone are ineffective in preventing NH_3 emissions, as concentrations will increase until the rate of release balances the rate of formation (and possibly addition from SCR slip).”	Refer to section 6.1.1 of this document for the BAT requirements associated with the carbon capture plants, specifically water wash and acid wash in sections 7.1 and 7.2 of the table, ‘Meeting the requirements for Post-Combustion Carbon Capture’.
Nitrosamines and nitramines No information has been given on nitrosamine accumulation or methods to limit or remove nitrosamines. The expected numerical levels of nitrosamines and nitramines present in the circulating solvent in long-term operation should be stated, with	In their response to our Schedule 5 Notice for further information dated 16/07/2024 the following additional evidence was provided: Nitrosamines and other degradation products only tend to accumulate in the absence of reclaiming, or if the reclaiming rate is insufficient to compensate for the degradation products generation rate. The method to limit accumulation to design levels – typically 1-2%

evidence to support these values; this information is obviously critical for assessing the impacts of planned and unplanned emissions to atmosphere.	in a commercial plant – is the use of the thermal reclaimer (which has built-in spare capacity to account for unexpectedly high degradation rates). In addition, nitrosamines tend to degrade in the CO_2 stripper, due to the high temperatures present, and as such, their accumulation rate will be slowed, and may reach a steady-state plateau, even in the absence of reclamation. In pilot plant units, a reclaimer is typically not used, and the degradation products are left to accumulate to much higher levels – up to 5-10% or higher, thus testing the solvent behaviour beyond the design conditions, and showing that its performance and behaviour does not change with excursions outside of the normal degradation products concentration window – which was also demonstrated in Boundary Dam operation. They also confirm that the nitrosamines emission figures are based on steady-state long-term operation. This is demonstrated in the table they provide for the pilot trials testing and the long-term operation of Boundary Dam and the Brothers CISA unit since 2014, which take account of solvent composition, and in particular degradation products concentration, in these conditions. The data that supports this design also accounts for long-term operation, as explained above, a wide range of degradation products concentrations has been tested at pilot scale. We have included a requirement to monitor solvent quality in table S3.4 of the Permit as described in section 8.3 of this document.
Comments about other issues	
Concern over controlling biological growths in the absorber water wash, with reference to the Boundary Dam capture plant which uses the same solvent (Improving the Operating Availability of the Boundary Dam Unit 3	In their response to our Schedule 5 Notice for further information dated 16/07/2024 the following additional evidence was provided: Issues that have occurred at Boundary Dam, with the potential to affect environmental performance, relate to the impact of gas

Carbon Capture Facility by Patit Pradoo, Brent Jacobs, Keith Hill, Sarah Wilkes, Jonathan Ruffini, Wayuta Srisang, Yuewu Feng, Doug Daverne, Conway Nelson :: SSRN). The potential effect on water wash performance.	contaminants on rates of solvent degradation along the different degradation pathways, resulting in an increase in emissions. While the BD3 unit is in compliance with its operating permit – notably with regards to amine/nitrosamine emissions - accumulation of contaminants such as iron results in higher ammonia emissions than for clean gas applications, such as the VPI CHP. Subsequent comparison with clean gas applications and other contaminated gas applications has allowed the technology provider to: • demonstrate that clean applications resulted in low emissions; • confirm model predictions of the impact of the different contaminants. This has been taken into account in the assessment of the VPI CHP flue gas quality and potential content of specific contaminants. The accumulation of degradation products beyond the design concentrations, with potential impact on emissions has been accounted for in the VPI design with an appropriate margin in the reclaimer processing capacity, as described in section 6.1.1 of this document for the BAT requirements associated with the carbon capture plants, specifically solvent selection in section 4.2 of the table, ‘Meeting the requirements for Post-Combustion Carbon Capture’.