

Permitting Decisions- Variation

We have decided to grant the variation for Humber Refinery operated by Phillips 66 Limited.

The variation number is EPR/UP3230LR/V021.

The permit was issued on 31/10/2025.

The variation is to permit a new post-combustion carbon capture (PCC) plant retrofitted to the Fluid Catalytic Cracking Unit (FCCU) of the Humber Refinery, in order to remove the carbon dioxide (CO₂) from the flue gas emitted from the unit.

The captured CO₂ is then exported offsite for offshore geological storage through an external transport and storage network beyond the boundaries of the permitted installation. There are two potential transport and storage networks that the Humber Refinery PCC Plant could be connected to: either the Viking CCS CO₂ gathering network or the East Coast Cluster Humber Low Carbon Pipelines, also known as Zero Carbon Humber, for transport to storage sites under the North Sea. These are not part of the permitted installation.

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.

1 Purpose of this document

This decision document provides a record of the decision-making process. It

- highlights the [key issues](#) in the determination
- summarises the decision making process in the [decision considerations](#) section to show how the main relevant factors have been taken into account
- explains why we have also made an Environment Agency initiated variation
- shows how we have considered the [consultation responses](#)

Unless the decision document specifies otherwise we have accepted the applicant's proposals.

Read the permitting decisions in conjunction with the environmental permit and the variation notice.

2 Key issues of the decision

2.1 Regulated activities and outline description of the proposal

The new post-combustion carbon capture plant will consist of a new EPR regulated activity, introduced in the permit by this variation:

- Section 6.10 Part A(1)(a) - Capture of carbon dioxide for geological storage: Post-combustion carbon capture of emissions from the FCCU Regenerator

A new effluent treatment plant, referred to as Purge Treatment Unit (PTU), treating the wastewater effluent generated from the flue-gas desulphurisation process introduced by this variation, will also consist of a new EPR regulated activity:

- Section 5.4 Part A(1) (a) (ii) - Disposal of non-hazardous waste in a facility with a capacity of more than 50 tonnes per day by physico-chemical treatment: Purge Treatment Unit

The FCCU operations are changed as a result of this variation, in that additional abatement units are retrofitted to the flue gas from the FCCU Regenerator, in order to meet the inlet specification for the post-combustion carbon capture plant. This consists of a substantial variation to the existing regulated activity, of which the Fluid catalytic cracking unit (FCCU) is part:

- Section 1.2 Part A(1) (d) - Refining mineral oil (Primary operations)

In the process configuration permitted prior to this variation, the flue gas from the FCCU passes through cyclones for the removal of entrained catalyst dust, then through either a restriction orifice chamber or a turbo-expander and a waste heat boiler. The flue gas is then routed through an electrostatic precipitator (ESP) to remove any remaining catalyst before entering the existing 115m tall stack (emission point A6b). In addition, emissions from the FCC Feed Heater (H3401) and the Isostripper Reboiler (H3631) are also routed directly to the existing 115m tall stack (Emission Point A6a). Start-up Heater H3402 also vents to Emission Point A6a, however this is only used once every 6 years for 1-2 days. This process configuration will remain until the activities permitted in the scope of this variation are fully constructed and commissioned into operation, as notified according to a pre-operational condition specified in the permit (PO9).

The new PCC Plant permitted by this variation will take the flue gas from the FCCU Regenerator only.

The flue gases emitted from the FCCU Feed Heater and the Isostripper Reboiler will not go to the PCC Plant as the pressure from these sources is too low and therefore would need numerous fans to drive the flue gas to the PCC Plant. As

such, these emission sources will continue to be released from the existing FCCU stack via Emission Point A6a.

The hot FCCU Regenerator flue gas will continue to be treated in the existing cyclones but will then pass through a number of new pre-treatment stages prior to entering the PCC Plant, in order to reduce the concentrations of oxides of nitrogen (NO_x), oxides of sulphur (SO_x) and particulate matter (PM) and also reduce the temperature of the flue gas. This is required to ensure the PCC Plant operates effectively and to reduce the potential for solvent degradation to occur. As such, the existing waste heat boiler and ESP will no longer be required and therefore will be removed.

The new flue gas pre-treatment stages will include a waste heat exchanger (to lower the flue gas temperature for treatment), a Selective Catalytic Reduction (SCR) unit to reduce NO_x, a Wet Gas Scrubber (WGS) to reduce SO₂ and particulates with an integrated Wet Electrostatic Precipitator (Wet ESP) to further reduce fine particulates and aerosols in the FCCU Regenerator flue gas. A waste heat exchanger will recover energy to be used in the PCC Plant.

The flue gas will then pass into the PCC Plant where it will travel up through a counter-flow, packed absorption column against a falling amine-based solvent (CANSOLV DC-103) into which the majority of the CO₂ content will be absorbed.

The treated flue gases (CO₂-abated flue gas) will then pass through abatement stages consisting of water wash and mist eliminator and will subsequently be released to atmosphere via a stack on top of the PCC Plant CO₂ Absorber Column (new emission point A6c).

The CO₂-rich solvent will leave the bottom of the CO₂ Absorber Column and, after being heated in a crossflow heat-exchanger, will be routed to the top of a CO₂ Stripper where it will pass down a packed column, in counter-current to hot rising vapour from the reboiler at the CO₂ Stripper base, releasing the absorbed CO₂. The CO₂-lean solvent at the bottom of the CO₂ Stripper will then return to the solvent system via the cross-flow heat-exchanger, and the CO₂ from the top of the CO₂ Stripper will pass to the CO₂ compression plant.

The water-saturated CO₂ gas from the PCC Plant will undergo staged compression to dense phase, with oxygen and water removal, to achieve the pipeline CO₂ specification. The dense phase CO₂ stream will then be transported off-site into the CO₂ T&S Network.

The PCC Plant will be designed to operate 24 hours a day, 7 days a week as per the existing Installation and will be designed for 95% CO₂ capture during steady state operation, capturing up to 0.5 million tonnes per year of abated CO₂.

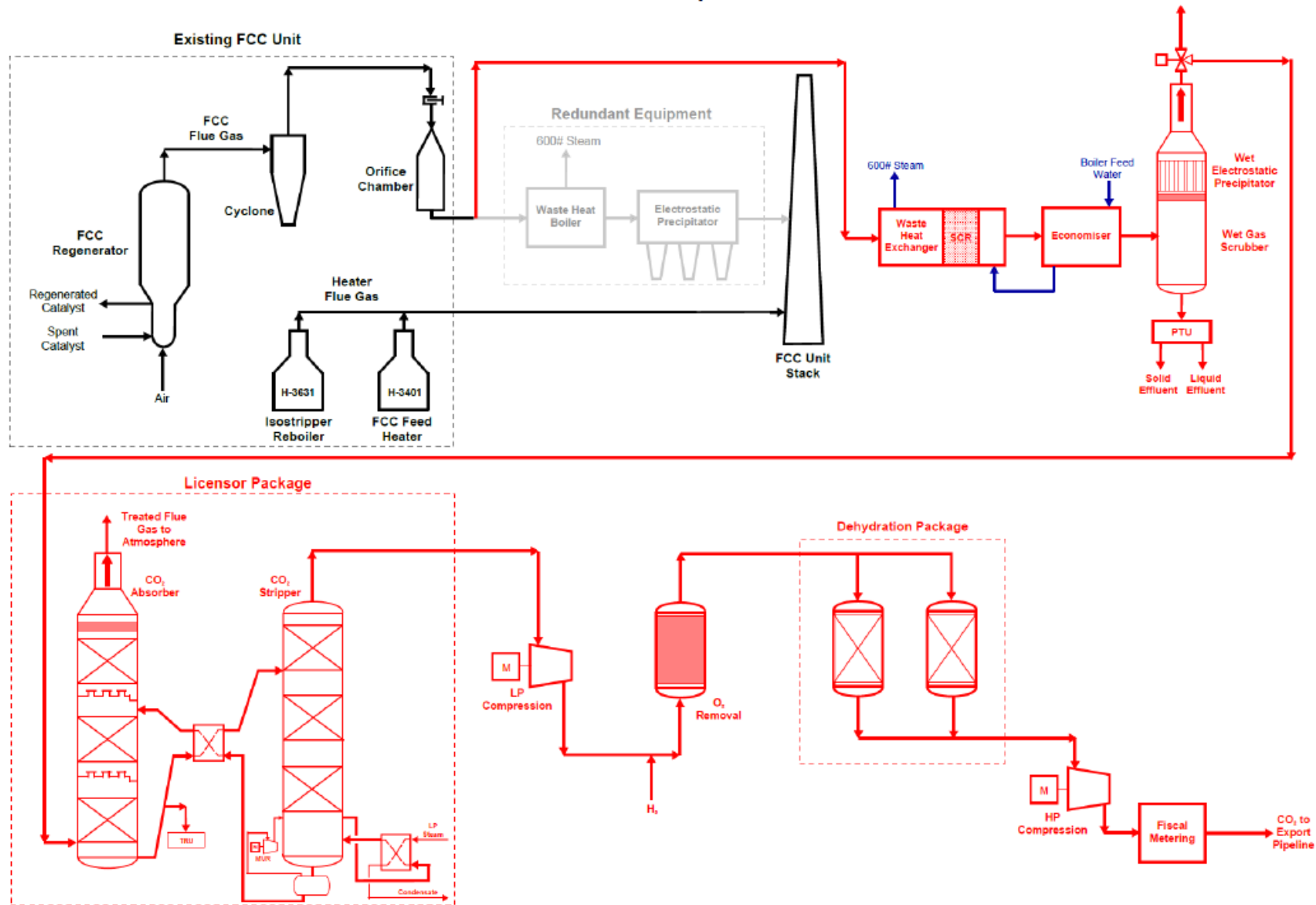
The PCC Plant will include the following main components:

- ducting to connect the FCCU to the PCC Plant;

- waste gas heat exchanger/ air-cooled heat exchangers;
- flue gas pre-treatment: SCR, WGS and Wet ESP;
- a Purge Treatment Unit (PTU) to treat the effluent from the WGS;
- a PCC Plant with a CO₂ Absorber Column and associated stack, and a CO₂ Stripper Column;
- LP CO₂ compression;
- oxygen removal and dehydration facilities;
- HP CO₂ booster compression;
- CO₂ pipelines connecting the PCC Plant to the compression facilities and the CO₂ T&S Network interface;
- chemical offloading, storage and distribution facilities for ammonia for the SCR, caustic for the WGS and amine-based solvent for the PCC Plant;
- a thermal Solvent Reclaimer Unit;
- utilities (including chillers, steam generator and air compressors);
- electrical substation; and
- instrument equipment house.

A simplified process flow diagram of the PCC Plant, reproduced from the application documents, is shown in the following:

Humber FCC Carbon Capture Schematic



2.2 Operating techniques and BAT assessment

The assessment of the operating techniques proposed for the installation against Best Available Techniques (BAT) is set out in the application document titled 'Humber Refinery Environmental Permit Variation Application Main Supporting Document', in the application duly made on 18/03/2024. Further information on how the proposed operating techniques compare against BAT was provided by the Applicant in response to the Schedule 5 Notice served on 16/07/2024 (responses received on 02/10/2024 and 29/11/2024). We have included the relevant application documents and responses to the request for additional information in table S1.2 of the environmental permit, as operating techniques that the operator will need to follow, according to condition 2.3.1 of the permit.

It should be noted that post-combustion carbon capture from mineral oil refining flue gases, and in particular from the FCCU regenerator process, is a novel concept that has not yet seen many commercial applications at an industrial scale. Hence, we consider the application to consist of emerging technologies.

Our BAT determination is therefore based on our current understanding of these emerging technologies and takes into account the fact that this is the first project developed in the UK for this type of installation. Our position on the determination of BAT for post-combustion carbon capture from refining processes is subject to change as we receive more applications for similar plants and we develop and consolidate our positions on specific BAT issues. This may also happen as the result of the continuous exchange of information and engagement with industry and other key stakeholders, the review of received applications and the regulation of the permitted sites brought into operation. We also refer to the consultation responses in section 4 for a summary of representations we have received from stakeholders in relation to this application, and how we have taken them into consideration as part of this variation determination.

We have determined BAT for the proposed installation with reference to the following guidance: 'Guidance on Emerging Techniques for Post-combustion carbon dioxide capture' ([Post-combustion carbon dioxide capture: emerging techniques - GOV.UK \(www.gov.uk\)](https://www.gov.uk/guidance/post-combustion-carbon-dioxide-capture-emerging-techniques)). This is published on our website. The BAT criteria referred to in the guidance are those set out in Annex III of the Industrial Emissions Directive (IED), as read in accordance with Schedule 1A to the Environmental Permitting (England and Wales) Regulations 2016.

2.2.1 Review of application against Guidance on Emerging Techniques for Post-combustion carbon dioxide capture ([Post-combustion carbon dioxide capture: emerging techniques - GOV.UK \(www.gov.uk\)](https://www.gov.uk/guidance/post-combustion-carbon-dioxide-capture-emerging-techniques))

The application is discussed in the following table against the key requirements set out in the guidance on emerging techniques (GET). Where applicable, reference is also made to the Refining of Mineral Oil and Gas BAT Conclusions (referred to as REF BAT Conclusions in the following). These are relevant to the activities carried out at the installation and, more specifically, to the operation of the FCCU: the applicable BAT conclusions have been referred to and highlighted throughout the assessment.

Table 1 – BAT / GET assessment

Ref. ^{Note 1}	Guidance on emerging techniques requirements	Our review of the Applicant's proposal	Compliant with BAT / GET?
2. Power Plant selection and integration with the PCC plant			
2.1 Energy efficiency in plants with PCC			
2.1.1	You must maximise the thermal energy efficiency of the power plant and of the supply of heat for the associated PCC plant.	<p>According to the applicant's assessment, power plant efficiency is not applicable, as the installation is not a power plant. However, opportunities for maximising thermal energy efficiency will be explored and integrated in the design of the PCC Plant. For instance, the waste heat from the FCC Unit flue gas will be used to generate steam for use in the PCC Plant.</p> <p>We agree these requirements are not applicable, refer to the following sections for our assessment of compliance with GET/BAT in relation to energy efficiency.</p>	N/A
2.1.2	You should refer to the LCP BREF or waste incineration BREF which give BAT definitions (BAT AELs) for the efficiencies of new and existing plants. Also refer to section 4.13 of the IED environmental	<p>Not applicable as the PCC Plant is a retrofit to an existing FCC Unit, not a power plant or a waste incinerator. The LCP BAT Conclusions and Incineration BAT conclusions are not applicable to the Humber Refinery. Section 4.13 of the referred guidance applies to installations generating energy from fossil fuels, hence it is not applicable.</p> <p>We agree these requirements are not applicable.</p>	N/A

Ref. ^{Note 1}	Guidance on emerging techniques requirements	Our review of the Applicant's proposal	Compliant with BAT / GET?
	<p>permitting regulations guidance on Part A installations.</p> <p>For natural gas power plants, lower heating value efficiencies of 60% or above without CO₂ capture are reported in the LCP BREF to be achievable for large-scale new combined cycle gas turbine installations.</p> <p>New biomass power plant efficiencies will depend on:</p> <ul style="list-style-type: none"> • the size and type of boiler • whether you use sub- or super-critical steam conditions 		
2.1.3	<p>You can reduce the impact of adding PCC by using power plant technologies that have the highest thermal efficiencies, since these have low specific CO₂ emissions (tonnes CO₂ per megawatt hour).</p> <p>If you expect to use more fuel to meet the heat or power needs of PCC, you should select the most efficient power plant</p>	<p>According to the application, specific energy efficiency measures built into the design include:</p> <ul style="list-style-type: none"> • Raising 600psig steam in a waste heat boiler, recovering the waste heat associated with the FCCU flue gas • Plate and frame exchangers used on the solvent circuit to maximise heat exchange efficiency; • Mechanical Vapor Recompression (MVR) i.e. a heat pump compressor on the CO₂ Stripper which recompresses vapour from flashing the lean amine to reduce duty on the associated reboiler; according to the application, the MVR saves a third of the duty required from the reboiler and therefore improves the energy efficiency of the plant; 	Yes

Ref. ^{Note 1}	Guidance on emerging techniques requirements	Our review of the Applicant's proposal	Compliant with BAT / GET?
	<p>technologies for that fuel and capture any additional CO₂ from that process. You should apply fuel input, electricity output and CO₂ emission metrics in the same way as you would to a power plant with fully integrated PCC (see section 2.3 on supplying heat and power for PCC operation).</p>	<ul style="list-style-type: none"> • Robust pre-treatment of the flue gas to remove contaminants and minimise fouling in the PCC Plant; • Recovering energy from the steam import by installing a steam let-down power-recovery turbine; and • Connection to the installation's 50 psig steam system to maximise recovery and use of low-grade heat from existing refinery processes from the Refinery processes. <p>Generic measures to maximise energy efficiency across the PCC Plant include:</p> <ul style="list-style-type: none"> • the plant components will be sized appropriately for the design capacity of the plant, so that each element is operating optimally and efficiently; • use of high efficiency motors and drives to minimise electricity load; • use of variable speed drives, where appropriate, to optimise power consumption; • the effective insulation of hot surfaces; and • regular planned maintenance in order to maximise the efficiency of the equipment and plant, with performance monitoring and audits to optimise the maintenance schedule. <p>According to the application, the energy performance of the system will be further refined during detailed design through an Energy Efficiency Value Improvement Practices study, to identify, validate and implement further opportunities. We have reviewed the proposed operating techniques related to energy efficiency and compared them against the requirements of our guidance on emerging techniques and BAT conclusion 2 of the REF BAT conclusions.</p> <p>We are satisfied that the proposed design meets BAT in relation to energy efficiency.</p>	
<p>2.2 Dispatchable Operation</p>			

Ref. ^{Note 1}	Guidance on emerging techniques requirements	Our review of the Applicant's proposal	Compliant with BAT / GET?
2.2.1	<p>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 CO₂ 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.</p>	Not applicable to retrofitting PCC to the flue gas from the FCCU regenerator.	N/A
2.3 Supplying heat and power for PCC operation			
2.3.1	<p>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:</p> <ul style="list-style-type: none"> • selected solvent • PCC plant configuration • CO₂ capture level • CO₂ delivery pressure 	<p>The application explains that the overall performance of the PCC Plant depends on the integration, as far as practicable, of electrical power and steam circuits and states that the CANSOLV DC-103 solvent and associated process configuration was selected to maximise this integration.</p> <p>On review we consider the proposed operating techniques meet the requirements of our guidance, even if the steam supply to the regenerator is imported from an external source (i.e. the adjacent VPI Immingham CHP Power Plant). This is because the proposal consists of retrofitting PCC to an existing refining process as opposed to a power plant. We consider that the supply of steam / heat to the carbon capture solvent regenerator depends on the complex integration of the refinery heat and material balance, whose off-gas is recovered as a fuel supply to the nearby VPI Immingham CHP power plant.</p>	Yes

Ref. ^{Note 1}	Guidance on emerging techniques requirements	Our review of the Applicant's proposal	Compliant with BAT / GET?
		We consider that the energy efficiency measures proposed in the design, including raising 600psig steam from the waste heat associated with the FCCU flue gas and using mechanical vapour recompression (MVR) are compliant with BAT and guidance on emerging techniques.	
2.3.2	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.	<p>The majority of heat and electricity will come from the adjacent VPI Immingham CHP Power Plant, as per the current site operations, which was previously determined to be compliant with REF BAT conclusion 2. There will be no additional ancillary plants for the generation of electricity, however heat recovery and reuse will be applied where possible, as described above.</p> <p>We consider this specific requirement of our guidance is not applicable to the retrofitting PCC to the flue gas from the FCCU regenerator.</p>	N/A
2.3.3	<p>The ratio between heat supplied as steam (or otherwise) and electricity output lost will depend on the:</p> <ul style="list-style-type: none"> • temperature at which you need to supply heat • steam condenser cooling water temperature <p>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.</p> <p>If the plant needs to supply heat for district heating, and extracting steam to supply</p>	We consider these requirements are not applicable to retrofitting PCC to the flue gas from the FCCU regenerator.	N/A

Ref. ^{Note 1}	Guidance on emerging techniques requirements	Our review of the Applicant's proposal	Compliant with BAT / GET?
	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.		
3.1 Purpose			
3.1.1	<p>The purpose of the PCC plant is to maximise the capture of CO₂ emissions for secure geological storage.</p> <p>You should aim to achieve a design CO₂ capture rate of at least 95%, although operationally this can vary, up or down.</p> <p>You will need to justify proposing a design CO₂ capture rate of less than 95% as an annual average of all normal operating conditions. You can submit a cost benefit analysis as part of your application.</p>	<p>In response to the Schedule 5 Notice served on 16/07/2024, the applicant confirmed that the PCC plant is specified to capture $\geq 95\%$ of the CO₂ in the treated flue gas and that all the design documentation and process guarantees are based on a CO₂ recovery of 95%.</p> <p>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 CO₂ capture efficiency.</p> <p>However, as the carbon capture parameter stated in the application is a design performance, 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 (IC32) 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.</p>	Yes, subject to approval of pre-operational / improvement conditions
3.1.2	<p>You will need to deliver CO₂:</p> <ul style="list-style-type: none"> at local transport system pressures (gas phase) 	According to the process description provided in the application, the water-saturated CO ₂ gas will undergo low-pressure (LP) compression to approximately 30 barg.	Yes

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	<p>such as 35 bar or dense phase such as 100 bar)</p> <ul style="list-style-type: none"> 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) 	<p>Hydrogen, supplied from the installation's existing hydrogen distribution system, will then be injected upstream of a deoxygenation reactor which will contain a platinum-based catalyst to promote the reaction of hydrogen with oxygen to produce water. The resulting water will then be removed from the CO₂ stream via a dehydration step, in order to meet the onward CO₂ pipeline specification.</p> <p>The dehydration unit will be a temperature swing adsorption process comprising beds of silica gel desiccant.</p> <p>The dehydrated LP compressed CO₂ will undergo further HP compression approximately 135 barg onsite prior to being transferred to the T&S Network via a metering station and then on to underground offshore storage (beyond the boundaries of this installation).</p> <p>The quality of the CO₂ will be monitored for compliance with export specifications for the temperature, pressure, water content, oxygen content, hydrogen content, CO, hydrogen sulphide, SO_x, NO_x and amines. In addition to quality monitoring, fiscal flow metering will be provided for custody transfer of CO₂ sent to the T&S Network. In response to our request for further information on the techniques implemented in the design to prevent or, where not possible, to minimise, carry over of solvent in the CO₂ gas separated from the stripping column, the applicant responded that the CO₂ Stripper includes a top overheads wash section, above the solvent inlet to the column, where the reflux from the overheads condenser is returned and used to capture droplets and vaporised solvent. The residual amines in the vapour phase will then almost completely condense in the condenser, due to their very low volatility at the condenser operating temperature.</p> <p>We are satisfied that the proposal meets the requirements of our guidance on emerging techniques in relation to delivery and conditioning of the captured CO₂.</p>	
3.1.3	The PCC plant must also have acceptable environmental risks through preventing or minimising	Dispersion modelling has been carried out to demonstrate that environmental quality standards for air emissions from the PCC Plant and their subsequent	Yes

Ref. ^{Note 1}	Guidance on emerging techniques requirements	Our review of the Applicant's proposal	Compliant with BAT / GET?
	<p>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:</p> <ul style="list-style-type: none"> • atmospheric dispersion and reaction modelling tools • specific site parameters which will define plant-specific ELVs 	<p>atmospheric degradation products will not be exceeded as a result of the PCC Plant operation.</p> <p>Refer to section 2.3.1 for our assessment of emissions to air. We are satisfied that the proposal meets the requirements of our guidance on emerging techniques in relation to environmental risks associated with emissions to air.</p>	
3.1.4	<p>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.</p>	<p>We consider this requirement of the guidance is not applicable to the retrofitting PCC to the flue gas from the FCCU regenerator as this does not consist of a power plant. As explained above (ref. 2.3), we are satisfied that the proposed plant meets BAT and the requirements of our guidance in relation to energy efficiency.</p>	N/A
3.2. Solvent Selection			

Ref. ^{Note 1}	Guidance on emerging techniques requirements	Our review of the Applicant's proposal	Compliant with BAT / GET?
3.2.1	<p>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 PCC evidence 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:</p> <ul style="list-style-type: none"> 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 	<p>The PCC Plant will utilise the Shell CANSOLV DC-103 solvent, and, according to the application, the plant has 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 submitted with the application. This assessment has taken into account both the direct and indirect impacts of nitrosamines resulting from anticipated amine and nitrosamines releases. Refer to section 2.3.1 for details of assessment of emissions to air.</p> <p>In the Schedule 5 Notice served to the applicant on 16/07/2024, we requested additional information on the solvent selection process, in particular:</p> <ul style="list-style-type: none"> Whether other solvents, in addition to monoethanolamine (MEA) which is referred to in the application, were considered, as part of the solvent selection process and the reasons as to why CANSOLV DC-103 has eventually been selected. A discussion of how CANSOLV DC-103 compares against MEA and other solvents considered in the selection process in terms of energy demand of the regeneration process, degradation and chemical stability of the solvent (including formation of nitramines, nitrosamines and heat stable salts), techniques to reclaim the degraded solvent; and toxicity profiles of the solvent components and their degradation products. <p>In the response received on 02/10/2024, the applicant confirmed that they carried out a technology review of available carbon capture technologies, considering open-art MEA or CESAR; proprietary amine-based solvents; non-amine based solvents; and alternative technologies, such as membrane solid absorption, fuel cells and phase change.</p>	Yes

Ref. ^{Note 1}	Guidance on emerging techniques requirements	Our review of the Applicant's proposal	Compliant with BAT / GET?
	<p>remove degradation products</p> <ul style="list-style-type: none"> 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 <p>The 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:</p> <ul style="list-style-type: none"> direct emissions of solvent components formation of additional substances in the PCC system and 	<p>According to the additional information provided, the technology review concluded that the only post combustion carbon capture technology proven at a comparable commercial scale, for which performance guarantees can be obtained to achieve the project's carbon capture target, was a proprietary amine-based solvent CO₂ capture process.</p> <p>A licensor qualification process was carried out and a short list of four viable technology providers capable of delivering the project were invited to bid for the Phillips 66 project scope. Following a review of the bids, the applicant identified the Shell CANSOLV technology to be the preferred option for their project. According to the applicant, Shell CANSOLV DC-103 was selected largely due to the technology supplier's ability to demonstrate scale-up of the technology and ability to back-up its high scoring performance data with performance guarantees, which is a major consideration in project financing.</p> <p>The applicant confirmed that solvent selection process included consideration of:</p> <ul style="list-style-type: none"> The energy demand of the regeneration process: detailed information on the energy efficiencies and performance of individual licensors' technologies is commercially confidential, and subject to Non-Disclosure Agreements. However, this information was used by Phillips 66 to compare and appraise the different solvents for a number of criteria including energy efficiency. Degradation and chemical stability of the solvent (including formation of nitramines, nitrosamines and heat stable salts): according to the response 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. The response recognised that the EA'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 	

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	<p>emissions of those substances</p> <ul style="list-style-type: none"> • formation of further additional substances in the atmosphere from emissions from the PCC system 	<p>in the flue gases. However, it is considered that the reclamation process included in the PCC plant design will enable any nitrosamines generated to be removed at the rate of generation, thereby minimising potential emissions. This is demonstrated by the low emission limit value proposed in the application for total direct N-amines (i.e. 0.003 mg/Nm³).</p> <ul style="list-style-type: none"> - Techniques to reclaim the degraded solvent: the degraded solvent will be reclaimed in a Thermal Reclaimer unit. A stream from the lean amine is continuously fed into Thermal Reclaimer, which is comprised 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 in pilot tests and reference projects. The applicant explained that the accumulation of degradation products beyond the design concentrations, with potential impact on emissions has been accounted for in the Phillips 66 design with an appropriate margin in the Thermal Reclaimer processing capacity. - Toxicity profiles of the solvent components and their degradation products. According to the response, the applicant 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 (EAL) currently applied to the assessment of impacts of generic nitrosamines (i.e. NDMA). Refer to section 2.3.1 for our assessment and conclusions on emissions to air, including consideration of derivations of EALs. <p>We are satisfied that the proposal meets the requirements of our guidance on emerging techniques in relation to the selection of the carbon capture solvent.</p>	
3.2.2	The potential for solvent reclaiming and other cleaning methods is also an important factor in solvent selection. You	The PCC Plant will include a solvent filtration unit which will take a slip stream of the solvent from the absorber for continuous cleaning. Most of the filtered solvent is routed to the Lean Solvent Cooler for reuse in the Absorber, however a further slip stream of this will go to the Thermal Reclaimer, which will also operate continuously.	Yes

Ref. ^{Note 1}	Guidance on emerging techniques requirements	Our review of the Applicant's proposal	Compliant with BAT / GET?
	<p>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:</p> <ul style="list-style-type: none"> • Recover a high fraction of the solvent in the feed to the reclaimer during reclaiming. • Minimise reclaimer wastes and that they can easily be disposed of. 	<p>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 CO₂ capture 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 it is anticipated that 82% of the feed to the thermal reclaimer will be returned to the solvent circuit 'clean'.</p> <p>In maximising solvent reuse on site, reclaimer wastes will be minimised as far as possible.</p> <p>In the Schedule 5 Notice served to the applicant on 16/07/2024, we requested additional information on whether any long-term pilot tests, or the operational experience gathered by the solvent supplier, support the conclusion that the proposed combination of solvent and reclaiming process is able to maintain a stable working solvent composition over long term operation. We also requested the applicant to provide evidence that proposed thermal reclamation is proven to be effective for the CANSOLV DC-103 solvent based on pilot plant testing or reference projects. See item below for additional information included in the response received on 02/10/2024.</p> <p>We are satisfied that the proposal meets the requirements of our guidance on emerging techniques in relation to the proposed techniques for reclaiming the carbon capture solvent.</p>	
	<p>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)</p>	<p>In the initial application documents the applicant represented that a pilot plant trial had not been carried out on the flue gases from the FCCU. However, the solvent provider carried out numerous pilot trials of the CANSOLV solvent on various different flue gas streams including Waste to Energy, natural gas-fired boilers, coal-fired boilers, blast furnaces and a cement kiln.</p>	

Ref. ^{Note 1}	Guidance on emerging techniques requirements	Our review of the Applicant's proposal	Compliant with BAT / GET?
	<p>flue gases and power plant operating patterns over a period of at least 12 months. You do not need to do this for your plant if information on the solvent performance is already available from pilots, tests, or regular operation at a similar plant.</p>	<p>In addition, CANSOLV has been commercially deployed since 2012, with the first large scale capture of CO₂ from a coal-fired power station (Boundary Dam) commencing in 2014.</p> <p>In the Schedule 5 Notice served to the applicant on 16/07/2024, we requested additional information on the lessons learnt from the pilot trials and operational experience gathered from the use of the CANSOLV solvent in relation to the solvent performance, and consideration given in the design process to any special characteristic of the FCCU flue gas in comparison to those of other flue gases tested in the referred pilot plants.</p> <p>The applicant responded providing the additional information on several CANSOLV pilot trials (refer to their response to our Schedule 5 Notice, received on 02/10/2024, and available on request from the public register), including a more recent trial carried out on catalytic cracker flue gas between February and August 2023 at the Technology Centre in Mongstad, in Norway. This campaign was aimed at testing operation with several CANSOLV DC-103 formulations (including the formulation to be used in the Phillips 66 PCC) with the two flue gas sources available at the TCM test centre (catalytic cracking off-gas and the CHP from the co-located refinery). Although the results of this campaign have not been publicly presented, the applicant reports that they confirm low emission levels in clean applications, including applications where the flue gas is inherently free of contaminants that can lead to solvent degradation, or applications like the Phillips 66 PCC where the flue gas is treated through an efficient gas cleaning system and does not contain particulate matter susceptible of releasing contaminants harmful to the solvent when captured by the post-combustion carbon capture system.</p> <p>According to the additional information provided, since 2019 most campaigns include the use of advanced instruments for continuous, low limits of detection monitoring of amines and degradation product emissions. The measurements performed allowed Shell to validate the structure of the emission prediction models, i.e. the contributions taken into account (components volatility, liquid entrainment,</p>	

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		<p>aerosols induced emissions) and the applicant remarked that tests performed with other CANSOLV solvent formulations were still relevant to inform the predictive model.</p> <p>We requested the applicant to explain the differences between the characteristics of the flue gas from the FCC Unit and other flue gases emitted from different processes tested in pilot plants. The applicant responded that different types of applications differ from the Phillips 66 flue gas in terms of inlet CO₂ concentrations (typically 15% volume for cracker flue gases) and contaminants in the flue gases. The contaminants present in the flue gases are relevant in terms of the resulting emissions, where flue gases with higher contaminants can lead to acceleration of solvent degradation (particularly where iron is present), or aerosol-promoted emissions. While the tests most representative of the Phillips 66 flue gas with regards to emissions are those performed on a Catalytic Cracker flue gas in 2023, the whole of range of tests is relevant, according to the applicant, as they allowed to determine the impact of flue gas composition, and particular the presence of contaminants – or absence thereof.</p> <p>We requested the applicant to provide evidence that adequate consideration was given to any of the special characteristics of the FCCU flue gas, in comparison to those of other flue gases tested in the referred pilot plants, when designing the flue gas pretreatment process prior to carbon capture and the carbon capture process itself. The applicant responded that Shell has extensive experience in processing FCC technology and in particular FCC off-gas cleaning, as well as in processing FCC flue gas in amine units, with two CANSOLV SO₂ capture systems in operation since respectively 2006 and 2011 in US refineries. They referred to the published results of test campaigns carried out at the Technology Centre Mongstad on the benefits of reducing the aerosol concentration in a residue FCC flue gas. They reported that the test campaign conducted by Shell looked at the impacts associated with: potential high NO₂ concentrations (resulting from high NO_x concentrations and/or high NO₂/NO ratios); presence and concentrations of SO_x</p>	

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		<p>leading to the formation of aerosols when the gas is quenched and cooled with a high risk of aerosol-induced emissions in the absence of mitigation; particulate matter with potential to release metals causing acceleration in solvent degradation. These risks have been mitigated by the selection of an exhaustive gas pre-cleaning system, including a wet ESP efficient for fine dust and acid mist removal, and sourced from a vendor with proven experience in the treatment of FCC flue gas. In addition, leaching tests have been performed in Shell laboratories to confirm the potential impact of this particulate matter. This has been taken into account in the design of the Phillips 66 proposed post-combustion plant, and in particular in the selection of the flue gas pre-cleaning system, and the tests performed to detect leaching of contaminants that could potentially degrade the solvent. Also, the accumulation of degradation products beyond the design concentrations, with potential impact on emissions has been accounted for in the Phillips 66 design with an appropriate margin in the Thermal Reclaimer processing capacity.</p> <p>We requested the applicant to explain whether any long-term pilot tests (i.e. run over a period of at least 12 months as required by our guidance), or the operational experience gathered at the Boundary Dam reference project operational since 2014, support the conclusion that the proposed combination of solvent and reclaiming process is able to maintain a stable working solvent composition over long term operations, without affecting the environmental performance and emissions profile of the plant, due to degradation of the solvent. The applicant responded that the reclaiming method proposed to be used at Phillips 66 (separation of amine and degradation products by vacuum distillation) is the same as used in the Boundary Dam and Brother CISA commercial units. They represented that the Brother CISA plant reclaimer has maintained the solvent working composition since start-up in 2014, i.e. for 10 years. The Boundary Dam unit has also demonstrated its capacity to separate amine and degradation products over the 10 years of operation, although due to the coal-fired nature of the power station, degradation rates were much higher than the design and exceeded its processing capacity. Additional reclaiming capacity – operating on the same</p>	

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		<p>principle had to be added. Learning from this has been taken into account in the design for new projects using Shell licensed technology by including sufficient spare capacity in the design of the reclaimer. Overdesign of the thermal reclaimer is proposed to deal with potentially higher NO₂ content than that used for the design basis and to prevent and mitigate uncertainties of the design in relation to efficiency of the absorber emissions abatement system, given that the application acknowledges this is a first of a kind project.</p> <p>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.</p>	
3.3 Features to control and minimise atmospheric and other emissions			
3.3.1 Flue gas cleaning			
	You will need to consider the following, depending on the flue gas source and the solvent selected.		
3.3.1.1	<p>Sulphur oxides (SO_x) removal (and hydrochloric acid (HCl) for EfW)</p> <p>Sulphur oxides (SO_x) removal can be in the power plant flue gas desulphurisation unit or in the PCC direct contact cooler. SO_x in the flue gas will readily react with amines to produce heat stable salts.</p>	<p>According to the application DeSO_x additive will continue to be used in the FCCU to reduce the loading on the WGS. The Wet Gas Scrubber (WGS) will further reduce SO_x concentrations in the flue gas from the FCCU prior to the PCC Plant. The applicant therefore considers that SO₂ will be reduced to levels that will minimise the generation of heat stable salts.</p> <p>We agree that the proposal meets the requirements of our guidance on emerging techniques as it reduces the levels of sulphur oxides in the flue gas through a combination of techniques in order to prevent degradation of the amine-based solvent associated with the generation of heat stable salts.</p>	Yes, subject to approval of pre-operational / improvement conditions

Ref. ^{Note 1}	Guidance on emerging techniques requirements	Our review of the Applicant's proposal	Compliant with BAT / GET?
	<p>These products are typically stable under reclaimer conditions, but the heat stable salt formation with SO_x can be, at least partly, reversed by alkali addition in the solvent reclaiming process.</p> <p>SO_x 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 SO_x removal (and HCl removal for EfW) is likely to be primarily an economic decision.</p> <p>SO_x levels in the exit flue gases from an amine PCC plant will be at extremely low levels.</p>	<p>We have also compared the proposed operating techniques against BAT 26 of the REF BAT conclusions (techniques to prevent or reduce SO_x emissions to air from the catalytic cracking process regenerator) and we consider the proposal consists of a combination of techniques that is compliant with the requirements of this BAT conclusions:</p> <ul style="list-style-type: none"> • Use of SO_x reducing catalyst additives (DeSO_x additive) as primary (process-related) technique; • Use of non-regenerative scrubbing (wet scrubbing) as secondary (end-of-pipe) technique. <p>According to the REF BAT Conclusions, the use of wet scrubbing as an end-of-pipe technique may be limited in the case where the by-products from treatment (including e.g. waste water with high level of salts) cannot be reused or appropriately disposed of.</p> <p>The scrubbing process results in an effluent with potentially high levels of particulate/fines, sulphur species and ammoniacal nitrogen, proposed to be disposed of in the liquid discharge from the refinery (emission point W2), after treatment in a dedicated effluent treatment plant, referred to as a Purge Treatment Unit (PTU). Refer to section 2.2.2.2 for further discussion of BAT in relation to the PTU.</p> <p>Characterisation of the PTU wastewater stream has been undertaken based on engineering studies carried out by the scrubber vendor. This information has been reviewed by the applicant and used to calculate the future emissions from the wastewater following its treatment in the PTU when combined and discharged with the existing Humber Refinery effluent.</p> <p>The PTU treated effluent consists of high concentrations of sulphates. For this reason, the applicant has carried out an appraisal of options to reduce the concentration of sulphates in the liquid effluent arising from the wet scrubbing of the</p>	

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		<p>FCCU regenerator flue gas. This appraisal is presented in section 5.2.1.3 of the application Main Supporting Document and considers the following techniques:</p> <ul style="list-style-type: none"> • Biological removal of sulphur compounds requires an Upflow Anaerobic Sludge Blanket (UASB) reactor, where the biological reduction of sulphate into sulphide takes place. The applicant has ruled out this option because the high sulphate level of up to 38,294 mg/l calculated for the PTU wastewater (in absence of DeSOx additive), is not considered suitable for biological treatment, according to the advice they have received from anaerobic treatment technology suppliers. • Membrane separation technologies. The applicant has ruled out this option because of the high dissolved solids concentration of the PTU effluent, in excess of typical seawater reverse osmosis membranes specification, and because this treatment method would only in effect concentrate the sulphate within the wastewater, and therefore there would still be a very high sulphate wastewater stream that would require disposal. • Ion exchange. The applicant has assessed that the high sulphate concentrations in the PTU wastewater make it unsuitable for ion exchange treatment. • Regenerative scrubbing with a proprietary solvent means that the SOx-absorbing reagent used in the scrubber can be regenerated for reuse. The resulting concentrated SO₂ stream also has the potential to be recovered, through additional appropriate processing technology, to liquid SO₂, sulphuric acid or elemental sulphur. There is therefore no sulphate containing effluent generated by this process. According to the application, regenerative scrubbing is suited to flue gas streams with a very high SOx concentration (i.e. 1,000 – 2,000ppm), higher 	

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		<p>than that from the FCCU flue gas (current ELV 800 mg/Nm³, although with actual emissions typically between 400 – 600 mg/Nm³), hence this option was discarded by the applicant. Regenerative scrubbing is one of the operating techniques reported as BAT in BAT conclusion 26 of the REF BAT conclusions. Examples of regenerative scrubbing processes reported in the REF BREF include inlet SO₂ concentrations of >1700 mg/Nm³ for the LABSORB™ regenerative scrubbing system at the ENI refinery in Sannazzaro (Italy) and 2000 – 7000 mg/Nm³ as the typical inlet concentration for the Wellman-Lord regenerative scrubber process. In the Schedule 5 Notice served to the applicant on 16/07/2024, we asked them to clarify whether the conclusion that the regenerative process was not suitable had been reached or validated with support from regenerative scrubbing process licensors / technology providers. The applicant responded that the information provided in the Main Supporting Document on regenerative scrubbing was based on detail provided by Shell for a CANSOLV regenerative scrubber system. They have reportedly two systems in operation in the US, and one in Germany, where inlet SO₂ concentrations are 1,200 – 1,500ppm, after an upstream Wet Gas Scrubber (WGS). In the information provided by Shell, they stated that for the Phillips 66 application with <400ppm in the flue gas into the unit, that the economics of regenerative unit are not viable. As detailed in the Main Supporting Document, the increased complexity of a regenerative scrubbing system versus the proposed non-regenerative unit adds considerable cost and complexity to the PCC plant project and also requires more plot space in the already plot-constrained PCC plant area at the Refinery. This is supported by information in the Refineries BRef, which states that “the applicability [of regenerative scrubbing] is limited to the case where regenerated by-products can be sold. For existing units, the applicability may be limited by the existing sulphur recovery capacity as well as by space availability”. When taking into account the justification provided by the applicant, the local constraints and environmental setup and the conclusions of the risk</p>	

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		<p>assessment of emissions to water, detailed in section 2.3.2 of this document, we are satisfied the proposed process configuration consisting of WGS technology is BAT for this application.</p> <ul style="list-style-type: none"> • Chemical precipitation of sulphates using calcium hydroxide or barium carbonate. This option was discarded as it would generate large quantities of sludge that would require disposal off site to landfill, therefore resulting in significant cross-media effects. • Use of DeSOx additive. DeSOx additive is currently already used in the FCCU Regenerator to reduce SOx concentrations in the resulting flue gas. The application therefore proposed to continue to use this additive at concentrations that achieve 50% SOx removal from the FCCU flue gas, in order to reduce the resulting sulphate concentrations in the combined wastewater effluent to 533 mg/l. However, the same document acknowledges that there may be potential to increase the amount of DeSOx additive further (to achieve up to 80% removal of SOx from the flue gas), and this would reduce the concentration in the Combined Future Effluent to W2 to approximately 360 mg/l and commits to explore this option further during the detailed design. In the Schedule 5 Notice served to the applicant on 16/07/2024, we requested the applicant to advise the current SOx reduction performance achieved by dosing the DeSOx additive and to provide a review of the technical, economical, operational, environmental constraints and uncertainties potentially affecting the ability to achieve up to 80% SOx reduction in the flue gas of the FCCU process, by increasing the dosing of the DeSOx additive. The applicant responded that the current DeSOx usage is approximately 165 kg/day, and it is considered that a 50 - 70% reduction in SO₂ is currently achieved. The normal operating case used for the design basis of the proposed new Wet Gas Scrubber (WGS) as part of the post-combustion plant pre-treatment, was based on a flue gas 	

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		<p>containing 0.03 vol% SO₂. This assumption was based on operating the FCC without the use of DeSOx additive.</p> <p>Whilst we acknowledge that this specification is more conservative, and therefore more robust in terms of design of the desulphurisation equipment, we note that the DeSOx will need to be dosed to achieve a suitable SOx removal level, in order to meet the sulphate emission levels stipulated in the application and reflected in the emission limit value specified at emission point W2 (refer to section 2.3.2 for the risk assessment of emissions to water and emission limits specified according to the outcomes of this assessment). In the current operation with DeSOx dosing, the flue gas achieves a typical concentration of 0.01 vol% SO₂. The applicant explained that the basis for the 50% removal performance for the SO₂ in the flue gas feed to the WGS is considered to be a conservative assumption for the future operation and allows room for uncertainty in design assumptions and the variability in the sulphur content of the feedstock being processed. Phillips 66 consider allowing for this degree of uncertainty in the calculations and assumptions used means that DeSOx addition could be further increased if, following commencement of operation, performance was not as anticipated. If a baseline case of 80% removal performance was used and SO₂ emissions/ sulphate in the Purge Treatment Unit (PTU) wastewater were higher than expected meaning that additional DeSOx addition was required, then the additional quantities of DeSOx needed to achieve further reduction in SO₂ would increase significantly, becoming economically and technically unviable due to the diminishing returns achieved. Therefore, a 50% reduction with DeSOx allows additional headroom for further DeSOx addition to be applied, should performance not be as anticipated once operation of the post-combustion carbon capture plant commences.</p> <p>We are satisfied with this justification and we have specified accordingly an improvement condition (IC39) requiring the applicant to review the dosing rate of DeSOx additive after the first year of operation of the carbon capture plant, to achieve an increase in the SOx removal rate above the baseline</p>	

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		<p>50% and attain a reduction in the concentrations of sulphates in the PTU waste water effluent.</p> <p>Refer to section 2.3.2 for our assessment of the environmental risks associated with the changes to water emissions associated with this application.</p>	
3.3.1.2	<p>NOx removal</p> <p>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 and EFW BREF) using selective catalytic reduction (SCR).</p>	<p>An SCR system is proposed to be installed to reduce NOx concentrations in the flue gas from the FCC Unit prior to the PCC Plant. We are satisfied the proposal meets the requirements of our guidance on emerging techniques in that it reduces NOx concentrations with a potential to cause degradation of the carbon capture solvent; and we note this is also compliant with REF BAT conclusion 24 on prevention or reduction of NOx emissions to air from the regenerator of the catalytic cracking process.</p> <p>According to the additional information on the specification of the SCR provided by the applicant in response to the Schedule 5 Notice served on 16/07/2024, this system is specified to achieve a minimum NOx reduction efficiency of 95%, with a maximum ammonia slip of 2ppmv on a dry basis (corresponding to 1.4 mg/Nm³). However, the proposed annual average ammonia ELV is 5 mg/Nm³ in order to allow for deviations from the maximum design specification.</p> <p>The proposed ELV for ammonia is compliant with the lower end of the BAT-AEL range specified in Table 2 of the REF BAT conclusions for emissions of ammonia to air from a combustion or process unit where SCR or SNCR techniques are used. Furthermore, the applicant has also explained that the generation of ammonia from the degradation of CANSOLV DC-103 is very limited for clean gas applications, and, according to this, they have proposed that the same ammonia ELV of 5 mg/m³ is specified at the top of the PCC absorber (emission point A6c). We consider this a conservative approach in terms of environmental protection provided. Refer to items 3.3.2.2 and 3.3.3.2 of this table for additional considerations on the potential emissions of ammonia due to solvent degradation and their abatement.</p>	Yes

Ref. ^{Note 1}	Guidance on emerging techniques requirements	Our review of the Applicant's proposal	Compliant with BAT / GET?
	<p>If necessary, it is expected that ammonia (NH₃) 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.</p>	<p>Ammonia was previously used in the existing ESP on site, and therefore ammonia slip was already emitted from the FCCU stack. The dispersion modelling assessment included ammonia slip from the PCC Plant. Refer to 2.3.1 for the risk assessment of emissions to air.</p> <p>In response to the Schedule 5 Notice served to the applicant on 16/07/2024, they described the process controls on the ammonia dosing system to prevent/minimise ammonia slip whilst achieving the specified SCR NOx abatement efficiency, as it follows: the aqueous ammonia will be pumped via the liquid ammonia feed control valve to the ammonia vaporiser where it will be mixed with hot dilution air and be vaporised. The vaporised ammonia will then be mixed with the flue gas upstream of the SCR catalyst via an ammonia injection grid, which will ensure homogeneous mixing of ammonia with the flue-gas which minimises the potential for ammonia slip. The flue gas NOx concentration at the outlet of the SCR will be analysed and a Proportional Integral Derivative (PID) control loop will modulate the liquid ammonia feed control valve, regulating the ammonia flow against the required level of NOx reduction in the flue gas leaving the SCR to ensure that the proposed NOx Emission Limit Value is achieved, and that ammonia slip is minimised.</p> <p>We consider the proposal is compliant with REF BAT conclusion 8, which specifies BAT is to maintain suitable operating conditions of the SCR or waste gas treatment systems, with the aim of limiting emissions of unreacted ammonia, and the associated BAT-AEL specified in the Table 2 of the REF BAT conclusions.</p>	
	<p>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.</p>	<p>Not applicable.</p>	

Ref. ^{Note 1}	Guidance on emerging techniques requirements	Our review of the Applicant's proposal	Compliant with BAT / GET?
3.3.1.3	<p>Aerosols</p> <p>Sulphur trioxide (SO₃) droplets and fine particulates should not be present in the flue gas. If they arise in the PCC process they can cause significant amine emissions.</p> <p>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.</p> <p>Aerosols might be present, for example, because of significant SO_x 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.</p>	<p>The Wet ESP is proposed to remove the fine particulates and aerosols, in particular sulphuric acid mist formed by the presence of sulphur trioxide (SO₃) in the flue gas prior to the CO₂ Absorber Column. If these are not removed, they act as a nucleus to form larger aerosols in the CO₂ Absorber Column which leads to increased amine emissions from the Absorber stack.</p> <p>Also, a mist eliminator will be located after the water wash section at the top of the Absorber Column to further minimise emissions of aerosols.</p> <p>We are satisfied that the proposed operating techniques meet the requirements of our guidance in relation to preventing and minimising aerosols emissions.</p>	Yes
3.3.1.3.1	<p>You should also carry out regular isokinetic sampling in the operational plant to assess total vapour and droplet emission levels.</p>	<p>In response to section 4b of application Form Part C3, the applicant confirmed that emission monitoring will be compliant with BS EN 15259. Subsequently, in response to the request for additional information included in the Schedule 5 Notice served on 16/07/2024, the applicant reiterated their commitment to ensure that all the proposed continuous emissions monitoring systems are designed to meet the requirements with the BS EN 15259 standard and the associated recommendations</p>	Yes, subject to approval of pre-operational / improvement conditions

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		<p>for sample locations and confirmed that this specification has been included in the project's detailed design phase scope of works.</p> <p>However, since the detailed design has not commenced yet, there is potential that during detailed design it may become evident that it is not practicable to achieve the recommended sample locations, for example if the restricted PCC plot area means that the required lengths of straight ducting cannot be achieved. Suitable sample locations will be assessed through Computational Fluid Dynamics (CFD) modelling or other suitable methods.</p> <p>In acceptance of the applicant's proposal we have specified in the permit variation a pre-operational condition (PO16) requesting the operator to confirm the detailed design meets the requirements of BS EN 15259 or to obtain written approval from the Environment Agency on deviations from this standard and assessment of suitability of the proposed alternatives.</p> <p>According to our normal practice, emission monitoring will also be subject to demonstration of compliance with this standard through improvement condition (IC35), after the plant in the scope of the application becomes operational.</p>	
3.3.1.4	<p>Other flue gas impurities</p> <p>You may need to remove materials in the flue gas that would accumulate as impurities in the solvent to lower concentrations than is required under the relevant BAT AELs. This is to ensure satisfactory PCC plant operation. Whether you need to do this will depend on the specific solvent properties and</p>	<p>According to the application, the WGS and Wet ESP will reduce particulates from the catalyst fines from the FCCU significantly over the current emissions. Correspondingly, emissions of metals will be very low and therefore will not impact on the solvent.</p> <p>We are satisfied that the proposal is compliant with our guidance on emerging techniques in this regard.</p> <p>We have also assessed the proposal against the REF BAT Conclusions; in particular BAT conclusion 25 – techniques to reduce dust and metals emissions to air from the catalytic cracking process (regenerator).</p> <p>As the operations of the FCCU are not affected by this variation, the primary (process-related) techniques remain unchanged. These were determined to be compliant with BAT as part of a previous permit review.</p>	Yes

Ref. ^{Note 1}	Guidance on emerging techniques requirements	Our review of the Applicant's proposal	Compliant with BAT / GET?
	<p>the effectiveness of the solvent management equipment (such as filtering and reclaiming).</p> <p>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.</p>	<p>In addition to retaining the existing cyclones separators, the proposed additional wet scrubbing and wet ESP are consistent with the combination of secondary (or end-of-pipe) techniques specified by BAT conclusion 25. We are therefore satisfied that the proposal is compliant with BAT in this regard. The emission limit for particulate matters emissions to air will be reduced from the current 50 mg/Nm³ specified in the permit for emission point A6b to 10 mg/Nm³ in the new process configuration for emission points A6c and A6d. This is at the lower end of the BAT-AEL range specified in Table 5 of the REF BAT conclusions for the combination of BAT operating techniques specified by BAT conclusion 25.</p> <p>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.</p>	
3.3.2 PCC system operation			
3.3.2.1	<p>Operating temperatures</p> <p>You must establish and maintain optimum temperature and appropriate limits in the solvent stripping process.</p> <p>Elevated temperatures can cause some thermal degradation of the solvent. But higher peak average temperatures during</p>	<p>According to the application, the PCC Plant design is such that it will operate at optimised conditions for the CANSOLV DC-103 solvent. The steam supply to the CO₂ Stripper has been selected because it has a saturation temperature that is lower than the degradation temperature of the solvent DC-103.</p> <p>We are satisfied that the proposal is compliant with our guidance on emerging techniques in this regard.</p>	Yes

Ref. ^{Note 1}	Guidance on emerging techniques requirements	Our review of the Applicant's proposal	Compliant with BAT / GET?
	<p>regeneration will also likely promote reduced energy requirements and higher CO₂ capture levels. You must balance both to ensure the right environmental outcome.</p> <p>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.</p>		
3.3.2.2	<p>Solvent Degradation</p> <p>You should minimise oxidative degradation of the solvent by reduced solvent residence times in the absorber sump and other hold-up areas. Direct O₂ removal from rich solvent may be developed in the future but has not yet been proven at scale.</p>	<p>According to the application, the PCC Plant design is such that it will operate at optimised conditions for the CANSOLV DC-103 solvent.</p> <p>According to the information provided by the applicant in response to a Schedule 5 Notice (received 02/10/2024), 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.</p> <p>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.</p> <p>The applicant's response is summarised in the following:</p> <p>The CANSOLV DC-103 solvent 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,</p>	Yes, subject to approval of pre-operational / improvement conditions

Ref. ^{Note 1}	Guidance on emerging techniques requirements	Our review of the Applicant's proposal	Compliant with BAT / GET?
		<p>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. 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. However, according to the information provided by the applicant, the generation of ammonia from CANSOLV DC-103 is very limited for clean gas applications. The use of an advanced and comprehensive flue gas cleaning system upstream of the PCC plant (i.e. SCR, Wet Gas Scrubber and Wet-ESP) for the Phillips 66 FCCU flue gas prior to the PCC plant will reduce potential contaminants, which could favour certain degradation pathways and therefore lead to higher degradation product emissions. Tests performed in Shell laboratories using particulate matter from the FCCU flue gas from the Humber Refinery have also demonstrated that no contaminants susceptible to increasing solvent degradation or ammonia generation were leaching from the particulate matter into the solvent. Achievement of the low ammonia emission level of 5 mg/Nm³ proposed as emission limit for the application 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.</p> <p>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).</p> <p>In addition, nitrosamines tend to degrade in the CO₂ 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.</p>	

Ref. ^{Note 1}	Guidance on emerging techniques requirements	Our review of the Applicant's proposal	Compliant with BAT / GET?
		<p>This is reflected in the low nitrosamine/nitramine emission level of 0.003 mg/Nm³ (direct emissions) proposed as an emission limit in 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.</p> <p>We are satisfied that the proposal is compliant with our guidance on emerging techniques in relation to consideration given to the potential degradation of the solvent, however we have set an improvement condition (IC33) 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.</p>	
3.3.3 Absorber emissions abatement			
3.3.3.1	<p>Water wash</p> <p>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 NH₃ emissions, as concentrations will increase until the rate of release balances the rate of formation (and possibly addition from SCR slip).</p>	<p>According to the proposal, 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. Additional space for increasing the packing within the water wash section has been included in the design, for in the event that amine emission concentrations are higher than those anticipated.</p> <p>We are satisfied that the proposed water wash, including provision for its expansion, meets the requirements of our guidance for water wash. Refer to item 3.3.3.2 of this table for a discussion of requirement for acid wash.</p>	Yes

Ref. ^{Note 1}	Guidance on emerging techniques requirements	Our review of the Applicant's proposal	Compliant with BAT / GET?
3.3.3.2	<p>Acid wash</p> <p>An acid or other chemically active wash or scrubber after the water wash will react with amines, NH₃ and other basic species and reduce them to very low levels (for example, 0.5 to 5mg per m³ per species or lower).</p> <p>You should implement an acid wash as BAT, unless:</p> <ul style="list-style-type: none"> • 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 <p>Depending on PCC system configuration, an absorber acid wash can also</p>	<p>According to the application, an acid wash is not considered necessary to further reduce amines, ammonia or other pollutants from the process, based on the anticipated emission concentrations.</p> <p>In the Schedule 5 Notice served on 16/07/2024, we requested the applicant to explain what set of data supported the conclusion that acid wash was not required and whether this data supported the conclusion that simple water wash, in absence of acid wash, will be sufficient to abate ammonia and solvent degradation products that might accumulate in the system and be emitted from the top of the absorber.</p> <p>The applicant's response, received on 02/10/2024, is summarised in the following:</p> <p>The emission limits proposed by the applicant for emission point A6c are as follows:</p> <ul style="list-style-type: none"> • Ammonia: 5 mg/Nm³ * • Total Amines: 1.1 mg/Nm³ * • Total N-amines (direct release): 0.003 mg/Nm³ * • Amide: 0.03 mg/Nm³ * • Formaldehyde: 0.07 mg/Nm³ * • Acetaldehyde: 0.20 mg/Nm³ * <p>* Concentrations normalised to reference conditions: 273K, 101.3kPa, dry, 3%v/v oxygen</p> <p>According to the applicant, the proposed limits were derived based on extensive solvent trials and performance guarantees that Shell have agreed with them.</p> <p>The applicant compared the proposed emissions levels with those reported for a pilot plant trial using an MEA based solvent (Maasvlakte) evidenced in the BAT review at BAT-for-PCC_v2_EfW_web-1.pdf (ukccsrc.ac.uk) where emissions are significantly greater and required acid wash. For example, prior to the acid wash, emissions of MEA from the PCC absorber were 1.2 – 26.8 mg/m³. The acid wash</p>	Yes, subject to approval of pre-operational / improvement conditions

Ref. ^{Note 1}	Guidance on emerging techniques requirements	Our review of the Applicant's proposal	Compliant with BAT / GET?
	<p>counteract NH₃ slip from an SCR system.</p> <p>If an acid wash is not fitted, you should consider a second water wash as an acid wash if:</p> <ul style="list-style-type: none"> • emissions performance is worse than expected • you wish to change to a more volatile solvent <p>An acid wash is not likely to trap aerosols.</p>	<p>was found to reduce MEA emissions to 1 – 3 mg/m³. The proposed emissions from the proposed PCC absorber proposed for the Humber Refinery are consistent with these values without the requirement for acid wash.</p> <p>Likewise, emissions of ammonia from the absorber in the PCC pilot plant trial at Maasvlakte were 15 – 20 mg/m³ under normal operation, and after the acid wash they were reduced to <5 mg/m³, <i>i.e.</i> the same as proposed from the Humber Refinery PCC plant without an acid wash.</p> <p>They concluded that the proposed emission concentrations from the Humber Refinery PCC plant are therefore already considered to be “at acid wash levels with a water wash”, as required by our guidance on emerging techniques to justify that an acid wash is not needed.</p> <p>They also explained 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.”</p> <p>Furthermore, they explained that acid wash introduces further engineering issues than just the disposal issue detailed in the BAT Review for PCC:</p> <ul style="list-style-type: none"> - The inclusion of an acid wash would require an additional packed section at the top of the CO₂ absorber column, including appropriate liquid distributors, demisters, etc. resulting in an additional absorber height of the order of 10m. This would impact on the loads of the absorber column and foundations, resulting in significant additional cost. - The introduction of an acid wash section would result in leakage of the acid solution to the amine section of the CO₂ absorber column. Such leakage 	

Ref. ^{Note 1}	Guidance on emerging techniques requirements	Our review of the Applicant's proposal	Compliant with BAT / GET?
		<p>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.</p> <p>The use of special absorber column internals to minimise this leakage (zero-leak chimney tray) would add pressure drop on the flue gas path (about 5 mbar), meaning that the addition of an acid wash could increase the flue gas pressure drop caused by the PCC plant by a further 20%. This additional pressure drop would need to be overcome by the flue gas blower, resulting in significant additional energy usage.</p> <p>They therefore concluded 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.</p> <p>In support of this conclusion, the applicant also referred to the air emissions risk assessment submitted with the application (and supplemented by the additional information received on 02/10/2024 in response to our Schedule 5 Notice), showing that the process contributions of amines emitted by the proposed carbon capture plant are insignificant when compared to the EAL for piperazine (i.e. PC<1% of EAL); the process contributions of N-amines are well below the EAL for NDMA (i.e. 21% of EAL at the most affected receptor); and the predicted ecological impacts are also considered to not be significant. Refer to section 2.3.1 for further details on the air emissions risk assessment.</p> <p>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.</p> <p>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</p>	

Ref. ^{Note 1}	Guidance on emerging techniques requirements	Our review of the Applicant's proposal	Compliant with BAT / GET?
		<p>carbon capture plant at the nearby VPI Immingham CHP Power Plant (refer to section 2.3.1 for further details).</p> <p>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.</p> <p>We note that direct emissions of nitrosamines are unlikely to dominate the total nitrosamine process contributions. 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 µg/m³ – refer to: NPL REPORT CSSC 0001).</p> <p>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.</p> <p>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.</p>	

Ref. ^{Note 1}	Guidance on emerging techniques requirements	Our review of the Applicant's proposal	Compliant with BAT / GET?
		<p>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).</p> <p>The applicant has assessed that allowing provisions to retrofit acid wash is not necessary, based on the reassurance and performance guarantees provided by the solvent technology licensor. We consider this is a commercial risk that the applicant is deciding to take, in that, if the abatement performance of the operational plant is not consistent with the anticipated performance, the operator will need to face the costs necessary to remediate the environmental performance. Considerations on the acceptability of commercial risks are beyond our regulatory remit.</p> <p>We consider that setting the stringent emission limits in the permit variation 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 variation notice and we will regulate the installation against these emission limits.</p> <p>We have specified an improvement condition (IC31) requiring the operator to confirm that the overall plant meets the emission limits to air and water, energy efficiency and carbon capture efficiency specifications stated in the application documents for variation V021. Where deviations from the specified environmental performance are identified, the operator will have to propose for approval by the Environment Agency any applicable remedial measures to make the operations compliant and implement them in accordance with the Environment Agency's written approval and within the approved timescales.</p>	

Ref. ^{Note 1}	Guidance on emerging techniques requirements	Our review of the Applicant's proposal	Compliant with BAT / GET?
3.3.3.3	<p>Droplet Removal</p> <p>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 SO₃ or other aerosol mists.</p>	<p>SO₃ and fine particulates in the flue gas that can lead to the formation of aerosols in the Absorber will be removed by the Wet ESP.</p> <p>In addition, a mist eliminator will be located at the top of water wash section to further prevent the entrainment of droplets and aerosols into the waste gases.</p> <p>We are satisfied that the proposal is compliant with our guidance on emerging techniques in this regard.</p>	Yes
3.3.3.4	<p>Stack Height</p> <p>Where modelling predicts that you may need to raise the temperature at the point of release to aid dispersion, you can:</p> <ul style="list-style-type: none"> • increase the design stack height • add flue gas reheating <p>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</p>	<p>Detailed dispersion modelling has shown that a stack height of at least 65m for the PCC Plant will ensure that pollutants released will not result in exceedance of any air quality standards.</p> <p>On the basis of the model results, it is not considered that flue gas reheating is required.</p> <p>Refer to 2.3.1 for the risk assessment of emissions to air.</p> <p>We are satisfied that the proposal is compliant with our guidance on emerging techniques in this regard.</p>	Yes

Ref. ^{Note 1}	Guidance on emerging techniques requirements	Our review of the Applicant's proposal	Compliant with BAT / GET?
	used for flue gas reheating (see section 4 on cooling)		
3.4 Process and emissions monitoring			
3.4.1	<p>Role of monitoring</p> <p>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.</p> <p>You must also carry out monitoring to show that resources are being used efficiently. This includes:</p> <ul style="list-style-type: none"> • energy and resource efficiency • capture efficiency • verification that the CO₂ product is suitable for safe transport and storage <p>Your permit application should include a monitoring plan for both a commissioning phase and routine operation.</p>	<p>The installation is required to monitor and report energy and resource efficiency figures. The PCC Plant operation will also be monitored continuously to report the resource and energy efficiency of the plant.</p> <p>We have specified energy efficiency and emission monitoring requirements for the operational phase of the activities in the scope of this application in the permit variation.</p> <p>According to the application, it is anticipated the commissioning plan, addressing monitoring details, will be developed further into the detailed design process, and therefore the applicant proposed that this was provided to the Environment Agency through a pre-operational condition within the Environmental Permit. We have accepted this proposal and specified a pre-operational condition (PO8) requesting the applicant to develop and submit for approval a Commissioning Plan, prior to starting up the carbon capture plant.</p> <p>Process control monitoring to ensure that degradation products do not build up in the PCC Plant will involve a weekly sampling and testing schedule for degradation products, as advised by the solvent supplier based on their operational experience.</p> <p>In the Schedule 5 Notice served to the applicant on 16/07/2024 we requested the suite of process parameters that will be monitored for the solvent quality and stability, along with standards and frequencies of monitoring. In their response, the applicant advised the following:</p> <p>Weekly (with frequency increased to daily on start-up):</p> <ul style="list-style-type: none"> - Opacity/ colour 	Yes, subject to approval of pre-operational / improvement conditions

Ref. ^{Note 1}	Guidance on emerging techniques requirements	Our review of the Applicant's proposal	Compliant with BAT / GET?
	<p>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.</p> <p>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.</p> <p>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.</p>	<ul style="list-style-type: none"> - Solvent concentration; - CO₂ loading; and - Foaming tendency. <p>Weekly at start-up, monthly to quarterly in steady-state operation:</p> <ul style="list-style-type: none"> - Amine and organic non-ionic degradation products by LCMS (Liquid chromatography–mass spectrometry); - Organic acids and salts by Ionic Chromatography; and - Metals by ICP (Inductively Coupled Plasma). <p>We are satisfied that the proposal is compliant with our guidance on emerging techniques in this regard. We have specified the process monitoring requirements in the varied permit, to ensure that degradation products do not build up in the PCC plant.</p> <p>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.</p> <p>Since detailed methodologies proposed to be used for the process monitoring of the solvent quality have not been advised by the applicant, we consider we need to specify a pre-operational condition (PO18) which requires the operator to provide this information.</p>	

Ref. ^{Note 1}	Guidance on emerging techniques requirements	Our review of the Applicant's proposal	Compliant with BAT / GET?
	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.		
3.4.2	<p>Point source emissions to air</p> <p>You must include monitoring to demonstrate compliance with the IED Chapter III ELVs and the LCP BREF BAT AELs at normalised conditions.</p> <p>You must also monitor for:</p> <ul style="list-style-type: none"> • ammonia • volatile components of the capture solvent • likely degradation products such as nitrosamines and nitramines <p>Your monitoring may be by either:</p>	<p>According to the proposal CEMS for monitoring of flue gases from the PCC Plant will be installed. In addition, CEMS will be installed on the WGS for in the event that the FCCU is required to operate in CO₂ unabated mode.</p> <p>Continuous emissions monitoring was proposed for the following pollutants at the emission points A6c (PCC Plant Absorber Stack) and A6d (WGS stack):</p> <ul style="list-style-type: none"> • Oxides of Nitrogen • Carbon Monoxide • Sulphur Dioxide • Ammonia <p>Continuous or extractive monitoring was proposed, according to on-going development of suitable monitoring techniques, for the following parameters at the emission points A6c (PCC Plant Absorber Stack):</p> <ul style="list-style-type: none"> • Total Amines • Nitrosamines • Amide • Formaldehyde 	<p>Yes (in general), subject to approval of pre-operational / improvement conditions</p> <p>No (for particulates), compliance delivered through conditions specified in the permit</p>

Ref. ^{Note 1}	Guidance on emerging techniques requirements	Our review of the Applicant's proposal	Compliant with BAT / GET?
	<ul style="list-style-type: none"> continuous emissions monitoring ('on line') periodic extractive sampling ('off line') – where aerosol formation is expected, this must be isokinetic <p>Emission sampling point must also comply with M1 sampling requirements for stack emission monitoring.</p>	<ul style="list-style-type: none"> Acetaldehyde <p>At this stage of the design, the precise location and configuration of the CEMS to emission point A6d (WGS stack) had not been decided yet. Two options were proposed:</p> <ul style="list-style-type: none"> Option 1 – One CEMS on emission point A6d on the stack prior to the diversion valve to the PCC plant, to cover WGS stack annual ELVs when PCC plant is offline and to demonstrate compliance with monthly bubble ELVs all the time, according to REF BAT conclusions 57 and 58. See sketch below for option 1 (reproduced from application documents): <div data-bbox="1205 699 1585 992" data-label="Diagram"> </div> <ul style="list-style-type: none"> Option 2 – Two CEMS on emission point A6d, A6d(i) to cover WGS stack annual ELVs when PCC plant is offline and compliance with monthly BRef Bubble ELVs when PCC plant is offline; A6d(ii) to cover compliance with monthly BRef Bubble ELVs when PCC plant is online. According to the sketch below (reproduced from application documents): 	

Ref. <small>Note 1</small>	Guidance on emerging techniques requirements	Our review of the Applicant's proposal	Compliant with BAT / GET?
		<div data-bbox="1182 300 1635 705" data-label="Diagram"> </div> <p data-bbox="822 746 1868 914">We consider either option is acceptable in principle, subject to the applicant demonstrating that the relevant requirements of BS EN 15259 and BS EN 14181 are met. We have specified a pre-operational condition (PO16, applicable to the design stage) and an improvement condition (IC35, relevant to the operational stage) accordingly.</p> <p data-bbox="822 957 1917 1260">Whilst the proposed continuous emission monitoring of emissions of ammonia in either option complies with the requirement of REF BAT conclusion 4, given the preliminary status of the design, we have decided to allow more flexibility by including the option of carrying out continuous monitoring of ammonia in the flue line between the WGS system and PPC Plant Absorber, along with periodic monitoring on the PPC Absorber stack (emission point A6c). This would be an alternative to carrying out solely continuous monitoring of ammonia on the PPC Absorber stack (emission point A6c), which might prove to be inaccurate due to the presence of mist droplets. We have specified a pre-operational condition (PO16) accordingly.</p>	

Ref. ^{Note 1}	Guidance on emerging techniques requirements	Our review of the Applicant's proposal	Compliant with BAT / GET?
		<p>We consider the proposal for monitoring emissions to air is consistent with our guidance on emerging techniques and REF BAT conclusion 4, except in relation to monitoring of particulates (see further discussion below).</p> <p>Only periodic extractive monitoring for particulates from both monitoring points was proposed. This is not in line with the requirement for continuous monitoring of dust specified in the REF BAT conclusions and current permit. The applicant justified their proposal on the basis that the wet ESP will significantly reduce the particulate emission concentrations released from the FCCU Regenerator. In the response to the Schedule 5 Notice received on 29/11/2024, the applicant further justified their proposal not to carry out continuous monitoring of particulates on the ground that, although the proposed emission limit value for these pollutants is 10 mg/Nm³, the proposed flue gas abatement configuration including cyclones, WGS and Wet ESP is expected to attain actual emission levels of less than 5 mg/Nm³; and that at these very low dust levels, CEMS can struggle to provide reliable monitoring data. The applicant referred to the wording in our former guidance M20 (now superseded by online guidance: Monitoring stack emissions: quality assurance of continuous monitoring - GOV.UK), stating that "<i>The error associated with the Standard Reference Method (SRM) increases significantly when the dust concentration is below 5 mg/m³. Great caution should be applied when making a QAL2 assessment on processes with dust levels lower than 5 mg/m³</i>". Additionally, M20 states that "<i>If a test report states that a particulate monitor cannot be calibrated due to very low emissions, then the output of the CEM will be qualitative. Whilst it may be possible to intuitively set the reading of the CEM to provide an output in mg/m³, such readings will be an approximation at best, with a strong likelihood of high levels of uncertainty. Unless it is possible to produce higher, representative emissions from the process, it is recommended that such readings should be disregarded for regulatory purposes when compared to an ELV, even if there is an apparent breach of the ELV.</i>"</p>	

Ref. ^{Note 1}	Guidance on emerging techniques requirements	Our review of the Applicant's proposal	Compliant with BAT / GET?
		<p>We have reviewed the justification proposed by the applicant and we consider that:</p> <ul style="list-style-type: none"> • The use of cyclone separators, wet scrubbing and ESP are all techniques included in the REF BAT conclusion 25 and that REF BAT conclusion 4 specifies continuous monitoring of dust emissions from the FCCU regenerator process, without exceptions based on the combination of abatement technologies; • Whilst our guidance recommends caution in the interpretation of the results and suggests that these should be regarded as indicative and discarded for regulatory purposes when compared to an ELV when a test report states that a particulate monitor cannot be calibrated due to very low emissions, the guidance does not suggest replacing continuous monitoring with periodic monitoring; • The requirement for continuous emission monitoring of dust emissions to air is consistent with the regulation and BAT conclusions specified for other industrial sectors which have stricter BAT-AELs for particulates in the range where our M20 guidance suggests higher uncertainty of the CEMS readings: for example the BAT-AEL range for channelled emissions to air of dust/particulates specified in Table 3 of the Waste Incineration BAT conclusions (2019) is 2-5 mg/Nm³; and despite this low BAT-AEL range, Waste Incineration BAT conclusion 4 still specifies continuous emissions of dust; this has been reflected in waste incineration permits that we regulate. • The proposed emission limit value at 10 mg/Nm³ is significantly higher than the levels at which our guidance acknowledges higher errors might occur (i.e. < 5 mg/Nm³) when undertaking continuous monitoring of particulate emissions; with this ample margin, we consider the scenario of inaccurate CEMS readings incorrectly suggesting an ELV breach is highly unlikely; 	

Ref. ^{Note 1}	Guidance on emerging techniques requirements	Our review of the Applicant's proposal	Compliant with BAT / GET?
		<ul style="list-style-type: none"> We consider that the use of continuous monitoring is BAT to monitor the performance of the abatement process, even if the readings are only taken as indicative under the circumstances specified by our M20 guidance. <p>We have therefore rejected the applicant's proposal to carry out only periodic extractive monitoring of particulates and we have specified continuous monitoring in table S3.1 of the permit for this parameter. However, in acceptance of the concerns raised by the applicant, we have also included the specification for periodic extractive monitoring, in addition to the legally required continuous monitoring. We consider we have discretion under our current guidance to disregard for ELV compliance purposes the readings of the CEMS, when low emission levels of dust and the CEMS calibration reports suggest these readings might be inaccurate.</p> <p>We have specified continuous CO₂ monitoring on top of absorber stack as appropriate to reference.</p>	
3.4.3	<p>Process control monitoring</p> <p>You should use process control monitoring or periodic sampling with off-line analysis to control the CO₂ capture and the quality of the solvent reclaiming. Parameters you can monitor include:</p> <ul style="list-style-type: none"> absorber solvent quality – percentage active solvent 	<p>The PCC Plant will include instrumentation to monitor and record CO₂ capture rates and purity.</p> <p>Sampling points will be provided to collect fluid samples of the solvent to ensure the quality of solvent reclaiming.</p> <p>As above, on the Schedule 5 Notice served to the applicant on 16/07/2024 we have requested the suite of process parameters that will be monitored for the solvent quality and stability, along with standards and frequencies of monitoring. We are satisfied with the solvent monitoring proposal submitted by the applicant, and we have included these process monitoring requirements in the permit.</p>	Yes

Ref. ^{Note 1}	Guidance on emerging techniques requirements	Our review of the Applicant's proposal	Compliant with BAT / GET?
	<ul style="list-style-type: none"> • CO₂ 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 • in water or acid washes and scrubbers – pH, conductivity, loading of abated substances, flow rate 		
3.4.4	<p>Monitoring of CO₂</p> <p>To meet the required specification, include:</p> <ul style="list-style-type: none"> • CO₂ mass balance • CO₂ in fuel combusted • total capture level (as a percentage) • CO₂ released to the environment 	<p>The applicant confirmed all these parameters will be monitored as part of the PCC Plant operation, we are therefore satisfied that the proposal is compliant with our guidance on emerging techniques in this regard.</p> <p>We have specified a pre-operational condition (PO8) to confirm the process monitoring methods as part of the commissioning planning.</p>	Yes, subject to approval of pre-operational / improvement conditions

Ref. ^{Note 1}	Guidance on emerging techniques requirements	Our review of the Applicant's proposal	Compliant with BAT / GET?
	<ul style="list-style-type: none"> • CO₂ quality 		
3.4.5	<p>Monitoring Standards</p> <p>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).</p> <p>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.</p> <p>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.</p>	<p>According to the application, any extractive monitoring carried out on the emissions from the PCC Plant will be carried out by MCERTS accredited contractors and UKAS accredited labs will be used for analysis.</p>	<p>Yes, subject to approval of pre-operational / improvement conditions</p>

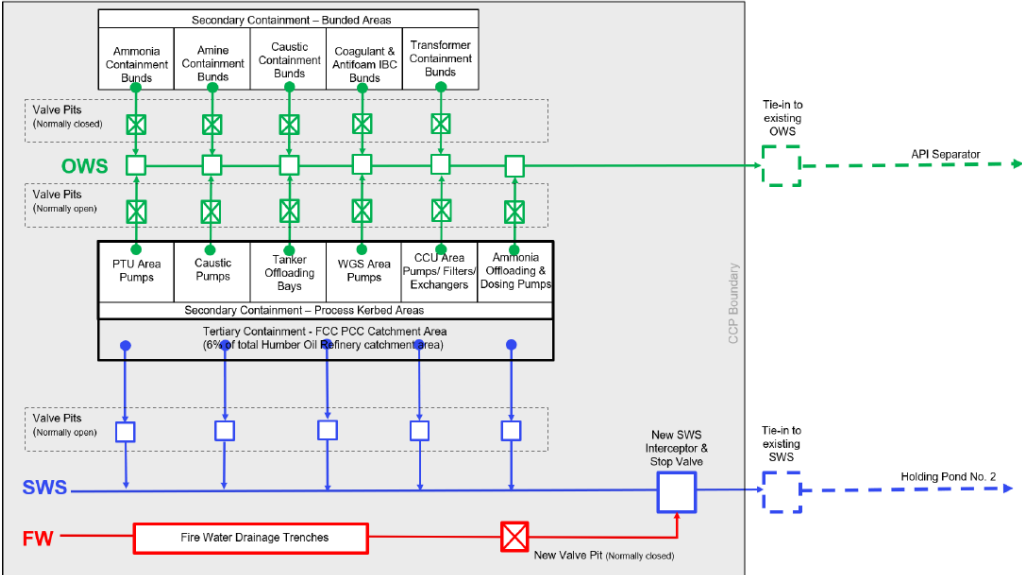
Ref. ^{Note 1}	Guidance on emerging techniques requirements	Our review of the Applicant's proposal	Compliant with BAT / GET?
	You must use a laboratory accredited by the United Kingdom Accreditation Service (UKAS) to carry out analysis for your monitoring.		
3.5 Unplanned emissions to the environment			
3.5.1	<p>You should propose a leak detection and repair (LDAR) programme that is appropriate to the solvent composition. This should use industry best practice to manage releases, including from joints, flanges, seals and glands.</p> <p>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.)</p>	<p>According to the BAT assessment provided in the application documents, the PCC Plant will be part of the Installation's maintenance and operations programme and LDAR programme and will include routine operator checks and the use of portable analysers to detect and monitor any leaks, as appropriate. Any leaks identified will be repaired by licenced contractors.</p> <p>In the following we discuss in more detail the operating techniques that relate to assessment, prevention and mitigation of unplanned and accidental emissions to the environment, and we assess how these compare against our guidance and BAT. Refer to item 3.6.2 for further details on assessment and management of other than normal operating conditions (OTNOC).</p> <p>Process control, safety and accidents Appendix J to the Main Application Supporting Document, document received on application duly made on 18/03/2024, provides a Qualitative Risk Assessment for the project, covering a high-level assessment of risks associated with fugitive emissions and accidents, along with the mitigation measures identified as part of the design or planned for the operation phase of the activities.</p> <p>Section 7.4.1.5 of the same document, sets out how the installation will assess, prevent and mitigate accidental events. In summary:</p>	Yes, subject to approval of pre-operational / improvement conditions

Ref. ^{Note 1}	Guidance on emerging techniques requirements	Our review of the Applicant's proposal	Compliant with BAT / GET?
		<p>The installation is an Upper Tier COMAH site and therefore has a site Safety Report which considers all the Major Accident and Disasters foreseeable at the site. According to the application, this will be updated to include considerations relating to the installation of the PCC Plant as needed.</p> <p>In addition, a Major Accident and Disasters assessment was carried out for the Environmental Statement supporting the planning application (Appendix B (see Volume I, Chapter 16)), which details the main hazards for the PCC Plant and identifies appropriate precautionary actions to prevent or mitigate potentially significant risks associated.</p> <p>According to the application, for the management of day-to-day minor accidents, an Environmental Incident Reporting and Classification procedure is in place for the Installation and will be amended to include the PCC Plant including all associated equipment prior to commencement of the PCC Plant's operation. A number of environmental protection measures will be implemented on site via the EMS to prevent and control spill events, including but not limited to:</p> <ul style="list-style-type: none"> • plans to deal with accidental pollution and any necessary equipment (e.g. spill kits) will be held within the PCC Plant area and all site personnel will be trained in their use. The EMS details how to appropriately deal with accidental spillages; • implementation of containment measures, including bunding for bulk storage tanks. All chemicals will be stored in accordance with relevant design and containment standards (i.e. CIRIA C736); • incorporation of interceptors into the drainage system to prevent spilled oils entering the surface water drainage system or local water bodies; and, • in case of a fire, the firewater will be contained on site and will subsequently be disposed of off-site if contaminated or processed through the onsite ETP. 	

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		<p>The EMS details controls in place to reduce emissions to air and/ or water during other than normal operating conditions (OTNOC) that includes the following elements:</p> <ul style="list-style-type: none"> • 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; • periodic assessment of the overall emissions during OTNOC (e.g. frequency of events, duration, emissions quantification/ estimation) and implementation of corrective actions if necessary. <p>The applicant committed to updating the relevant management systems, and procedures and protocols will be amended to include the PCC Plant prior to commencement of operations.</p> <p>In the Schedule 5 Notice served to the applicant on 16/07/2024 we asked for additional information on the emergency control and shut-down systems included in the design.</p> <p>The applicant responded on 29/11/2024, confirming that an emergency shutdown system, independent of the process control system, will be provided; and that process instruments will be specified as required to provide the necessary safety and environmental protections; safety and environmental hazards will be identified through the HAZOP and quantified using Layer of Protection Analysis (LOPA) to ensure specific protection layers and assigned trip Safety Integrity Level (SIL) levels provide the necessary risk reduction.</p> <p>In the same request for information, we asked the applicant to provide a description of all the design safety and operability studies undertaken as part of the design of the installation or planned for the detailed design stage and to explain how these will</p>	

Ref. ^{Note 1}	Guidance on emerging techniques requirements	Our review of the Applicant's proposal	Compliant with BAT / GET?
		<p>address potential environmental impacts associated with OTNOC conditions and accidents (including fires, explosions and loss of containment scenarios); and explain how the outcomes of these studies will be implemented in the design of the proposed carbon capture plant, and operating procedures as part of updating the installation's Environmental Management System and the site's Accident Management Plan / Emergency Response Plan.</p> <p>The applicant responded that a Quantitative Risk Assessment (QRA) was carried out to help inform plant layout and ensure that the proposed layout minimises the risk to neighbouring populations.</p> <p>A Process Hazard Analysis (PHA) (HAZOP) will be conducted during the next design phase (FEL3), which is currently planned to be carried out during 2025 - 2026. This will include a LOPA of all significant consequence hazards and associated SIL analysis of all required Safety Instrumented Systems.</p> <p>After PHA, the next step will be to address (reduce risk to As Low as Reasonably Practicable (ALARP)) identified gaps in the design or to inform development of the PCC plant operating procedures, which will be completed to the greatest extent possible in the FEL3 project phase.</p> <p>Following the project's Financial Investment decision (FID), revalidation of the PHA will take place during the project detailed design phase. This second PHA will confirm the resolutions to the next steps in the initial PHA are satisfactory and assess elements of the design not covered in the initial PHA (as a result of design changes or further definition to the FEL3 design such as compressor seal and lubrication systems etc.). Next steps from the second PHA (and any outstanding issues from the initial PHA) will be completed and approved in the detailed design project phase.</p> <p>An ENVICON study (following Humber Refinery Process HR-TEC-ENV-010 'Guidance on Env Screening of Projects and Mods') will be completed during the</p>	

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		<p>FEL3 stage of the project. This study will specifically identify and address any potential environmental impacts the new PCC plant processes may have, providing further, more detailed analysis than that covered by the PHAs. All next steps from the ENVICON study will be completed during the FEL3 and detailed design project phases.</p> <p>A fire prevention and protection philosophy and design will be developed and finalised throughout the project FEL3 and detailed design phases.</p> <p>The applicant anticipates that an update to the COMAH report will be needed as the planned modifications to the Electrostatic Precipitator affect an existing COMAH scenario. Potential impacts of the PCC plant on COMAH risks will also be considered. Review and updates of the COMAH report will be instigated and carried out during FEL3 design and will be concluded during detail design following project FID. Completed detailed design information and PHA are necessary pre-requisites for reviewing and updating the COMAH scenarios.</p> <p>Drainage philosophy and containment systems According to the application, all the chemicals will be stored in accordance with relevant design and containment standards (i.e. CIRIA Report 736 - Containment Systems for the Prevention of Pollution, Secondary, tertiary and other measures for industrial and commercial premises).</p> <p>According to the application, all the above ground storage tanks will be located within appropriately sized and constructed bunds, in line with CIRIA 736. All bulk liquid chemicals stored will be kept in bunded controlled areas with a volume of at least 110% of storage capacity, where the bund contains a single vessel, or 25% of the total system volume where the bund contains multiple vessels. In some instances, the governing factor for the bund size will be layout and/ or the space required for the tanks rather than the volume required for containment, and</p>	

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		<p>therefore some bunds will be larger than 110%/ 25% rule. Bulk chemicals will be appropriately segregated.</p> <p>The design includes segregated drainage systems that we consider compliant with REF BAT conclusion 11, use of interceptors into the drainage system to prevent spilled oils entering the surface water drainage system or local water bodies; and, in case of a fire, the firewater will be contained on site and will subsequently be disposed of off-site if contaminated or processed through the onsite effluent treatment plant.</p> <p>The drainage philosophy is depicted in the following schematic reproduced from the response to the Schedule 5 Notice served on 16/07/2024 and received on 02/10/2024 and described in the following.</p>  <p>The diagram illustrates a complex drainage system with multiple levels of containment. At the top, 'Secondary Containment - Bunded Areas' includes Ammonia, Amine, Caustic, Coagulant & Antifoam IBC, and Transformer bunds. Below these are 'Valve Pits (Normally closed)' and 'OWS' (Oil Water Slurry) lines. A second set of 'Valve Pits (Normally open)' is located below the OWS lines. The 'Secondary Containment - Process Kerbed Areas' includes PTU Area Pumps, Caustic Pumps, Tanker Offloading Bays, WGS Area Pumps, CCU Area Pumps/Filters/Exchangers, and Ammonia Offloading & Dosing Pumps. Below this is 'Tertiary Containment - FCC FCC Catchment Area (6% total Humber Oil Refinery catchment area)'. The system also features 'SWS' (Surface Water) lines with 'Valve Pits (Normally open)', 'FW' (Fire Water) lines with 'Fire Water Drainage Trenches' and a 'New Valve Pit (Normally closed)', and a 'New SWS Interceptor & Stop Valve'. The system is connected to an 'API Separator' and 'Holding Pond No. 2' via 'Tie-in to existing OWS' and 'Tie-in to existing SWS' connections. A 'CCP Boundary' is also indicated.</p>	

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		<p>In line with the existing installation, the PCC Plant area's drainage will comprise two segregated drainage systems: Oily Water Sewer (OWS) and Surface Water Sewer (SWS). The connections of the two drainage systems to the existing installation's effluent treatment plant (ETP) are depicted in the schematic shown in Figure 7 of the Application Main Supporting Document, and is not reproduced here.</p> <p>Uncontaminated surface water that can be collected in the PCC Plant area's SWS drainage will comprise rainwater falling on non-process areas of the PCC Plant and CO₂ compression areas. This will include paved areas, building roofs, roads and parking areas. In addition, process areas that do not contain equipment requiring frequent or routine maintenance and equipment where potential leakage may occur will also go to the SWS. The PCC Plant area SWS will tie into the Installation's existing SWS prior to the existing Tilted Plate Interceptor (TPI) oil/water separator, after which the stream can be routed either through the Refinery ETP, or to the No.2 Holding Pond and to offsite discharge at Emission Point W2.</p> <p>Potentially contaminated surface waters will drain to the PCC Plant area's OWS. This will include waters collected in bunded areas, kerbed areas, road tanker loading/ unloading areas and where there is intentional drainage of equipment during normal operation, maintenance or shut down. The PCC Plant area's OWS will tie into the existing Refinery's OWS prior to the existing API Separator (oil/water separator) and then be treated in the existing ETP.</p> <p>During routine operation there will be process wastewaters generated from a number of operations. Wherever possible, this water will be recycled back into the process, however where this is not possible, it will be routed to the OWS provided that the ETP can treat the wastewater and ensure that the existing ELVs are met. Water that does not meet this criterion will be taken offsite for treatment by a 3rd party licenced waste contractor.</p>	

Ref. ^{Note 1}	Guidance on emerging techniques requirements	Our review of the Applicant's proposal	Compliant with BAT / GET?
		<p>The Waste Heat Exchanger will be subject to continuous and intermittent blowdown, as required, however this is not considered to contain any pollutants which are not already present in site wastewaters and therefore this will be sent to the PCC Plant area's OWS.</p> <p>Firewater containment for the Refinery is designed in line with COMAH requirements, specifically ensuring there is <i>"sufficient capacity to hold safely the anticipated or foreseeable volume of hazardous liquids, including firewater, compatible with the intended operational characteristics"</i>. A detailed study has been carried out to assess the tertiary containment for the existing Humber Refinery site, which culminates in the completion of a holistic Environmental Risk Assessment. In the PPC plant area, bunded/ kerbed areas containing equipment will not be sized to contain the firewater deluge volumes, as the applicant considered that such an approach would be impractical and result in grossly oversized bunds/ kerbed areas. In the event of a fire or the activation of a deluge system, bunds/ kerbed areas will discharge via the PCC plant's SWS drainage system into the existing Refinery SWS. However, new firewater drainage trenches in the PPC plant area will provide additional drainage capacity, if required to ensure firewater effluents are confined to the process area (tertiary containment). The firewater trenches are normally isolated from the SWS to provide some attenuation capacity and allow effluent rates into the downstream SWS to be controlled and potentially contained if contaminated. The provision of these trenches is aligned with existing installations on the Refinery site. Tertiary containment for the PCC plant area will be provided by the existing Humber Refinery provision, and will also include any new kerbing, sub surface structures and the OWS and SWS drainage systems to be installed in the PCC area. New OWS and SWS drainage will be sized to ensure that additional capacity to the tertiary containment on site is provided, and to contain the modelled hydraulic pressures.</p> <p>In the response to the Schedule 5 Notice served on 16/07/2024 and received on 29/11/2024, the Applicant confirmed that there are no identified or anticipated</p>	

Ref. ^{Note 1}	Guidance on emerging techniques requirements	Our review of the Applicant's proposal	Compliant with BAT / GET?
		<p>design scenarios for effluents containing amines to be drained to the existing ETP. In particular:</p> <ul style="list-style-type: none"> The water used in the water-wash section of the absorber will be continuously recycled to the solvent loop as solvent make-up water. This is a closed loop system, hence there is no direct way that the water bleed could be drained to the ETP. <p>The water removed during the CO₂ compression process will be recovered into the solvent loop, to minimise wastewater generation where possible, and therefore this represents normal operation. If it is not possible for the water to be recovered to the solvent loop then there is potential that this water could be used as dilution water for the solvent storage tanks or in the wet ESP. Use in the ESP is currently being investigated and will be dependent on the potential for there to be amines present within this water, which would preclude its use for this purpose.</p> <p>An alternative use would be as dilution water to the degraded solvent drum, which collects the reclaimer bottoms, as some dilution water is required for this prior to it being sent off-site for disposal.</p> <ul style="list-style-type: none"> The drainage philosophy also includes a closed Solvent Drain specifically designed to drain the PCC plant process equipment in the event of maintenance activities: process solvent would be drained into dedicated sumps in the closed Solvent Drain where it is either returned to the process units, returned to solvent storage tanks or sent offsite for disposal. <p>We are satisfied that the general design principles for the drainage and containment systems stated in the application and in response to the Schedule 5 Notice are consistent with BAT and meet the requirements of our guidance in relation to preventing and, when not possible mitigating, the risks of accidental releases to environment. However, since the design still needs to be finalised, we have specified a pre-operational condition (PO12) requiring the Applicant to submit for approval by us the details of the final design of secondary and tertiary containment</p>	

Ref. ^{Note 1}	Guidance on emerging techniques requirements	Our review of the Applicant's proposal	Compliant with BAT / GET?
		systems and their isolation philosophy, to be developed according to CIRIA report 736.	
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.	See 3.1.1	Yes

Ref. ^{Note 1}	Guidance on emerging techniques requirements	Our review of the Applicant's proposal	Compliant with BAT / GET?
3.6.2	<p>You should set out any potential 'other than normal operating conditions' (OTNOC) for the CO₂ 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.</p> <p>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 CO₂ transport and storage network is down.</p>	<p>OTNOC scenarios, including those entailing abnormal emissions of carbon dioxide, and the associated operating techniques to manage them have been identified in the application and in response to the Schedule 5 Notice served to the applicant to an extent that we consider satisfactory.</p> <p>The pre-operational conditions (PO10 and PO19) specified in the permit will ensure that the installation's EMS will be updated to cover accidents, emergencies and OTNOC.</p> <p>Further details on OTNOC are provided in the following:</p> <p>In the Schedule 5 Notice served on 16/07/2024 we asked for additional information on OTNOC scenarios associated with the malfunctioning of new flue-gas abatement systems and associated air emissions risks. In their response of 29/11/2024, the applicant provided a review of these scenarios.</p> <p>They identified the scenarios that could be classed as other than normal operating conditions (OTNOC) during a Structured What-IF-Technique (SWIFT) review, which is a check-list led safety assessment of the PCC plant design. The scenarios identified within the Selective Catalytic Reduction (SCR), Wet Gas Scrubber (WGS) and Wet Electrostatic Precipitator (Wet ESP) packages that led to consequences of increased emissions were detailed in a spreadsheet included in the response. We refer to this document, available from the Public Register, for details.</p> <p>Safeguards were identified from the SWIFT review, which included preventative and post-event remedial actions and further actions being included within the plant design to provide additional controls to reduce the risk of these scenarios occurring. The actions captured as part of the SWIFT review will be subject to further engineering design reviews through next stages of the design and detailed design. In their response, the applicant assessed risks to air associated with increased emissions of NO_x, SO_x and particulates, and impacts to the downstream PPC plant, associated with the malfunctioning of the SCR, WGS and WESP:</p>	Yes, subject to approval of pre-operational / improvement conditions

Ref. ^{Note 1}	Guidance on emerging techniques requirements	Our review of the Applicant's proposal	Compliant with BAT / GET?
		<ul style="list-style-type: none"> • If the SCR was not operational at all, the concentration of NO_x to the PCC plant would be the same as current FCC flue gas concentrations which do not have SCR abatement. These were shown in Graph 5.3 of the Main Supporting Document to be well below 300 mg/Nm³ and therefore well within the risk envelope included in the Air Impact Assessment carried out to support the Environmental Permit variation application. Refer to section 2.3.1 for our review of the air emissions risk assessment. An increase in NO_x to the absorber could potentially result in increased amine degradation in the solvent, however N-amine emissions would be minimised by ensuring that degradation products do not build up in the solvent. The Thermal Reclaimer has been designed to ensure that it can remove a higher proportion of N-amines than expected in the base design, and therefore the risk of a significant increase in N-amine emissions is considered to be minimal. • If the WGS was not operational, the upstream SO₂ concentration with DeSO_x additive addition is approximately 480 mg/Nm³ and therefore well within the risk envelope included in the Air Impact Assessment carried out to support the Environmental Permit variation application (i.e. short term SO₂ emissions assessed at 600 mg/Nm³). Particulates would increase towards the WGS inlet levels of 170 mg/Nm³. Particulates were modelled at 10 mg/Nm³ in the Air Impact Assessment which could be exceeded for short periods of time (less than 1 hour) during an OTNOC scenario but would be unlikely to be exceeded for 24 hours, which is the averaging period for the assessment of ambient short-term particulate impacts. Therefore, no ambient air quality exceedances would be expected from any such event. 	

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		<ul style="list-style-type: none"> • If the WESP was not operational, SO₃ levels would increase, which would lead to an increased risk of aerosols and hence increased particulate/ amine/ N-amine emissions from the PCC plant. The potential increase in particulate emissions would be no worse than those discussed for the WGS. Increases in N-amines would be minimised by ensuring that degradation products do not build up in the solvent, through the overdesign of the Thermal Reclaimer system. <p>The application includes a description of the concentrated carbon dioxide venting scenarios and proposed operating techniques for venting of these streams during other than normal operating scenarios. According to the application (application document titled 'CO₂ Venting & Dispersion Report' document no. 215005-00857-00-PM-REP-00001 dated 15th December 2023):</p> <ul style="list-style-type: none"> • The CO₂ compression system is provided with an unlit CO₂ vent stack for the safe disposal of CO₂ to atmosphere. Any venting of CO₂ will be in line with applicable Health and Safety Executive (HSE) guidelines. Suitable automated systems will be installed to provide for early detection and warning of CO₂ release or leak that will allow plant personnel to move to a place of safety in sufficient time to prevent harm from occurring. • All concentrated CO₂ vents shall be routed via a common atmospheric vent (NGR grid reference 515601, 416926) referred to in the application as the CO₂ vent stack. Sources venting through the CO₂ vent stack will include: LP vent (unheated, flow controlled), HP vent (heated, flow controlled), export vent (heated, flow controlled) and relief valves vents (not yet designed). • With the exception of relief vents, flowrates shall be regulated across a flow control valve to ensure specified venting flowrates are maintained. For high pressure vents on the compressor discharge and export line, venting will be 	

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		<p>via an inline knock out drum and heater to ensure liquids/ solids formed from the high pressure let down are vaporised prior to venting to atmosphere.</p> <ul style="list-style-type: none"> • Start-up – It is proposed to recycle off-specification CO₂ back to the absorber inlet for all phases of plant start up. Excess CO₂ will be discharged along with the flue gases to atmosphere via the absorber vent. At this point it will be a diluted stream and no venting of concentrated CO₂ will occur. • Shut-down - Venting of concentrated CO₂ will take place as part of a planned operation when the PCC unit is shutdown. This is required to 'strip' CO₂ from the solvent prior to being sent to storage and to de-pressurise the LP and HP systems prior to purging and maintenance. Shutdown will coincide with the FCCU outage once every 5 years. During shutdown, flue gases from the FCCU will be vented to atmosphere via the wet gas scrubber and the flow to the carbon capture stopped. As the CO₂ flow reaches the minimum turn down for the Deoxy and Dehydration units, there is potential the CO₂ will go off-specification. At this point concentrated CO₂ would be discharged to the CO₂ vent stack via the LP and HP vents until stripping of CO₂ from the solvent has ceased. On completion of solvent stripping the final phase of the CCU shutdown is to de-pressurise the HP and LP stages of the compressor. Venting rates shall be controlled to ensure peak discharge rates are within those for CO₂ stripping. • CO₂ Off-Specification - Continuous analysis is provided in both the LP and HP systems. Where possible this would provide early indication of material going out of specification and allow corrective action to be taken ensuring atmospheric venting is minimised. It shall be necessary however to vent CO₂ if off-specification CO₂ is detected. 	

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		<ul style="list-style-type: none"> ○ In the event of LP going out of specification, flow to the HP system is stopped and flow to the LP system is reduced to the minimum turndown for the Deoxy and Dehydration units and recycled back to the absorber inlet. CO₂ is then vented along with the flue gases via the absorber vent as a diluted stream and no venting of concentrated CO₂ will occur. ○ In the event of HP going out of specification, flow to the HP system is stopped and flow to the LP system is vented to the absorber as per LP out of specification. De pressuring of the HP system would however be through the HP vent to atmosphere as a concentrated CO₂ stream via the CO₂ vent stack. Depressurisation of the HP line would occur at a flow governed by the capacity of the HP vent heating system. <ul style="list-style-type: none"> ● Relief Valve Discharges - Relief valves including those identified on the LP and HP compressor suction drums shall discharge concentrated CO₂ to atmosphere via the CO₂ vent stack. Relief venting shall however be infrequent and only in the event of plant upset. Determination of required relief provisions and sizing will be conducted at detailed design along with dispersion modelling as necessary to ensure discharged CO₂ concentrations are acceptable. <p>We are satisfied that adequate consideration was given to OTNOC in the application and additional information received in response to the Schedule 5 Notice and that the operating techniques stated are compliant with REF BAT Conclusion 7.</p> <p>We consider the range of measures, studies and techniques described in the Application, when adequately implemented throughout the design, construction, commissioning, operations and maintenance of the proposed activities, are adequate</p>	

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		<p>and consistent with BAT. For major accident hazards, we refer to the regulation of the proposed activities under the COMAH regulatory regime and the updated Safety Report for the installation.</p> <p>We have set a pre-operational condition (PO10) requiring the applicant to confirm the extension of the existing installation Environmental Management System, including accident response plans maintenance and LDAR programmes, to the PCC plant and associated equipment, prior to the beginning of its operations.</p> <p>We have set a pre-operational condition (PO19) requiring the applicant to develop a specific OTNOC Management Plan for the PCC plant, as required by our guidance on emerging techniques.</p> <p>We are satisfied that the proposed operating techniques for venting of carbon dioxide meet the requirements of our guidance in relation to mitigation of the risks of releases to the environment during OTNOC. We have included the application document ('CO₂ Venting & Dispersion Report') describing these operating techniques in table S1.2 of the permit, listing the operating techniques that the operator must follow in the operations of the installation.</p> <p>Refer to section 2.3.1.2 for the outcomes of our review of the assessment emissions of carbon dioxide submitted by the applicant. Since the design of the proposed activities was still preliminary at the time of the application, in line with our more recent guidance we have also specified a pre-operational measure (PO11) in the permit that will require the operator to provide a venting management plan to include details of the techniques to be used to manage the risks from the venting of large quantities of CO₂ for approval, following completion of the final design and prior to starting-up the proposed activities.</p>	

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3.6.3	<p>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 CO₂ capture during these periods, including during start-up and shutdown, to maintain high average capture levels.</p> <p>You should therefore capture CO₂ 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.</p>	<p>According to the application, considerations of the intermittency of power generation is not applicable to the proposed PCC plant, as the FCCU runs at relatively rateable loads while online, and has planned unit outages at 5 year intervals. There will be short periods on start-up, when the compression plant may not generate CO₂ of the required quality for delivering into the T&S Network. The deoxygenation, dehydration and cooling process during compression may take 15 – 30 minutes to meet the required specification. As such CO₂ may be vented to atmosphere during this time.</p> <p>We are satisfied that the requirements of our guidance for capture of CO₂ during plant start-up and shutdown are not applicable to the process configuration in the scope of the application, given the normally steady-state operations of the FCCU.</p>	N/A

Ref. ^{Note 1}	Guidance on emerging techniques requirements	Our review of the Applicant's proposal	Compliant with BAT / GET?
	<p>If your PCC plant is not initially constructed with this capability, your permit application should show how you may retrofit it.</p> <p>Your PCC OTNOC management plan should include measures to minimise any CO₂ emitted during start-up and shutdown periods.</p> <p>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.</p> <p>Where the CO₂ 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 CO₂. You will need to make sure the PCC plant is bypassed so that electricity, CHP generation or waste incineration can</p>		

Ref. ^{Note 1}	Guidance on emerging techniques requirements	Our review of the Applicant's proposal	Compliant with BAT / GET?
	<p>continue. You must not include these periods in any capture efficiency calculation, but you must keep a record of these, and CO₂ quantities emitted for reporting purposes.</p> <p>The CO₂ transport and storage system (including non-pipeline transfer) may sometimes need to be constrained – that is, it cannot take all the CO₂ you are producing. You should plan how you would meet this constraint as far as is practicable.</p> <p>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 shutdown.</p>		
3.7 Compression			
3.7.1	You should select CO ₂ compressors based on the expected duty. You	According to the application, the type of compressor will not be confirmed until later in the detailed design process, however the intention is that an integrally geared unit will be employed, undertaking both the LP and HP compression stages to maximise the efficiency and to minimise the number of compression trains.	Yes

Ref. ^{Note 1}	Guidance on emerging techniques requirements	Our review of the Applicant's proposal	Compliant with BAT / GET?
	<p>vibration. In particular, CO₂ compression could be an area of concern.</p> <p>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:</p> <ul style="list-style-type: none"> • 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 		

Ref. ^{Note 1}	Guidance on emerging techniques requirements	Our review of the Applicant's proposal	Compliant with BAT / GET?
	<ul style="list-style-type: none"> change of the frequency of the sound 		
3.8.2	<p>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</p>	<p>According to the application, the CANSOLV DC-103 solvent has very low volatility and therefore is not considered to represent a particular odour risk. We have requested a BAT assessment for the potential emissions associated with the storage of solvent. Also, the ammonia tank will not be vented to the atmosphere. Refer to section 2.2.2.1 for further details.</p> <p>The permit includes condition 3.4.2 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.</p> <p>We are satisfied that the necessary controls will be in place to control odour.</p>	Yes
4. Cooling			
4.1	<p>You will be able to achieve the best power and CO₂ capture plant performance by using the lowest temperature cooling available. You should use the hierarchy of cooling methods as follows:</p> <ul style="list-style-type: none"> direct water cooling (such as seawater) wet cooling towers hybrid cooling towers 	<p>According to the application, cooling will be provided from the existing installation's cooling water system and additional air cooling. The balance between water and air cooling will be managed within constraints of available water.</p> <p>The Environment Agency has assessed the availability of water resources within the Humber area, as part of Environmental Capacity for Industrial Clusters project (refer to Environmental capacity for industrial clusters: Humber pathfinder project (publishing.service.gov.uk)).</p> <p>This research has shown that water availability is a limiting factor for the development of low and zero carbon technologies in the area, and in particular on the South Humber bank, where the installation is located. We therefore consider that the proposed use of dry air-cooling technologies for the additional cooling duties of the project is BAT for this installation. Furthermore, since the proposed</p>	Yes

Ref. ^{Note 1}	Guidance on emerging techniques requirements	Our review of the Applicant's proposal	Compliant with BAT / GET?
	<ul style="list-style-type: none"> dry cooling – direct air-cooled condensers and dry cooling towers 	PCC is retrofitted to an existing refinery process that does not entail power generation and does not rely on the temperature of the cooling medium to achieve satisfactory levels of energy efficiency, we consider that the hierarchy of cooling methods stated in our guidance on emerging techniques is not applicable to the activities in the scope of this application.	
4.2	<p>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.</p> <p>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</p>	Not applicable to the process configuration in the scope of the application.	N/A

Ref. ^{Note 1}	Guidance on emerging techniques requirements	Our review of the Applicant's proposal	Compliant with BAT / GET?
	temperature limits may be an issue for direct cooling.		
4.3	<p>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:</p> <ul style="list-style-type: none"> • directly – such as using a rotary gas-gas heater • indirectly – such as using a heat transfer fluid or low-pressure steam 	Heat from the FCCU will be used to generate steam for use in the PCC Plant. Direct cooling is not used. As it is not considered that flue gas reheating is required, the rejected heat will have beneficial use elsewhere in the PCC Plant. We are satisfied the proposed operating techniques meet the requirements of our guidance in relation to heat recovery for the purpose of cooling the flue gases from the FCCU.	Yes
4.4	Lean and rich solvent storage may also help you achieve	According to the application, this requirement is not considered to be relevant to the retrofitting of carbon capture to the refining process. Taking into account the limited	N/A

Ref. ^{Note 1}	Guidance on emerging techniques requirements	Our review of the Applicant's proposal	Compliant with BAT / GET?
	satisfactory PCC performance during periods of high cooling demand.	cooling load of the PCC plant retrofitted to the FCCU and the limited impact of the cooling effectiveness on the overall efficiency of the process, when compared to a power station, we agree with this conclusion.	
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.	According to the application, due to the limited cooling load compared to a power station air cooling, it is not considered that this guidance is relevant. We agree with this conclusion.	N/A
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 .	Refer to section 2.3.2 for the assessment of emissions to water from the activities in the scope of the application.	Yes
5.2	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 '.	Consideration of plume dispersion modelling into estuaries and coastal waters are not applicable to the activities in the scope of the application, since the effluent from the Humber Refinery is discharged into the South Killingholme Drain, which is considered a freshwater body.	N/A

Ref. <small>Note 1</small>	Guidance on emerging techniques requirements	Our review of the Applicant's proposal	Compliant with BAT / GET?
Note 1: the reference numbers throughout the table reflect the numbering of the relevant sections of the online guidance: 'Post-combustion carbon dioxide capture: emerging techniques - GOV.UK (www.gov.uk)'			

2.2.2 Other BAT considerations and emission limits

2.2.2.1 Emissions from storage

In response to the Schedule 5 Notice served to the applicant on 29/11/2024 requesting additional information on the techniques used to minimise fugitive emissions from storage, the following additional information was provided:

The vapour pressure of CANSOLV DC-103 was incorrectly stated as <0.13 kilopascal kPa at 20°C in Section 4.8 of the application Main Supporting Document. The correct vapour pressure 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 lower than that of other common amine solvents such as MEA (0.05 kPa at 20°C).

The technology provider also confirmed that the solvent 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 measures in the Emissions from Storage BRef show the total atmospheric solvent losses to be 0.38 kg/year.

Although this may be considered acceptably low, the applicant conducted an assessment to appraise the benefits of the following emission controls measures:

- base case – insulated atmospheric storage with no painted finished, with heater (at 30°C);
- Option 1 - storage in white / milled finish tanks;
- Option 2 - low pressure nitrogen blanket; and
- Option 3 - high pressure nitrogen blanket.

Although reductions in venting losses were achieved with all the options, given the low losses of 0.38 kg/year associated with the base case, the applicant proposed that the significant additional capital cost to provide tanker vapour balancing and / or nitrogen blanketing was not justified. For comparison, we have calculated that the fugitive emissions estimated by the applicant are a negligible fraction (0.02%) of the emissions of amines from the top of the absorber.

In addition, and as stated above, it was confirmed that, unlike other amine-based solvents, 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. A suitable process control system will be put in place to monitor the tanks such as rate of loss.

The applicant proposed that further consideration of specifying a white painted or milled finish storage to reduce losses will be given during the detailed design stage.

Since this aspect of the design has not been finalised yet, we have set a pre-operational condition (PO17) requiring the final design of the solvent storage tanks to consist of white painted or milled finish as a minimum or to propose alternative / additional measures to reduce emissions from storage from these tanks.

In the Schedule 5 Notice served to the applicant we requested additional information on the operating techniques proposed to prevent and minimise fugitive emissions of ammonia with a potential to cause odour impacts to nearby receptors. In their response, the applicant confirmed that, according to the design developments of the project, the ammonia tank will consist of an unvented, nitrogen blanketed pressurised storage, with balanced tanker loading. As a consequence, the applicant considered that there is minimal potential to cause odour impacts at nearby receptors. Furthermore, the applicant assessed that the nitrogen blanketing will ensure that vapour space will not be flammable, to prevent and mitigate fires and explosion risks.

We are satisfied that the necessary controls will be in place, and we consider them to represent appropriate techniques for the facility, when also taking into account the requirements of the specified pre-operational condition we have specified in the variation and consolidation notice.

2.2.2.2 BAT assessment of effluent treatment

The effluent treatment activities included in the scope of this variation application, in addition to the existing effluent treatment already carried out at the Humber Refinery, consist of the proposed Purge Treatment Unit (PTU) to treat the purge stream blown down from the WGS flue gas abatement process. This continuous purge is needed to ensure that the scrubbing liquor recirculated in the WGS abatement does not accumulate suspended solids and dissolved compounds which are removed from the flue gas scrubbing process.

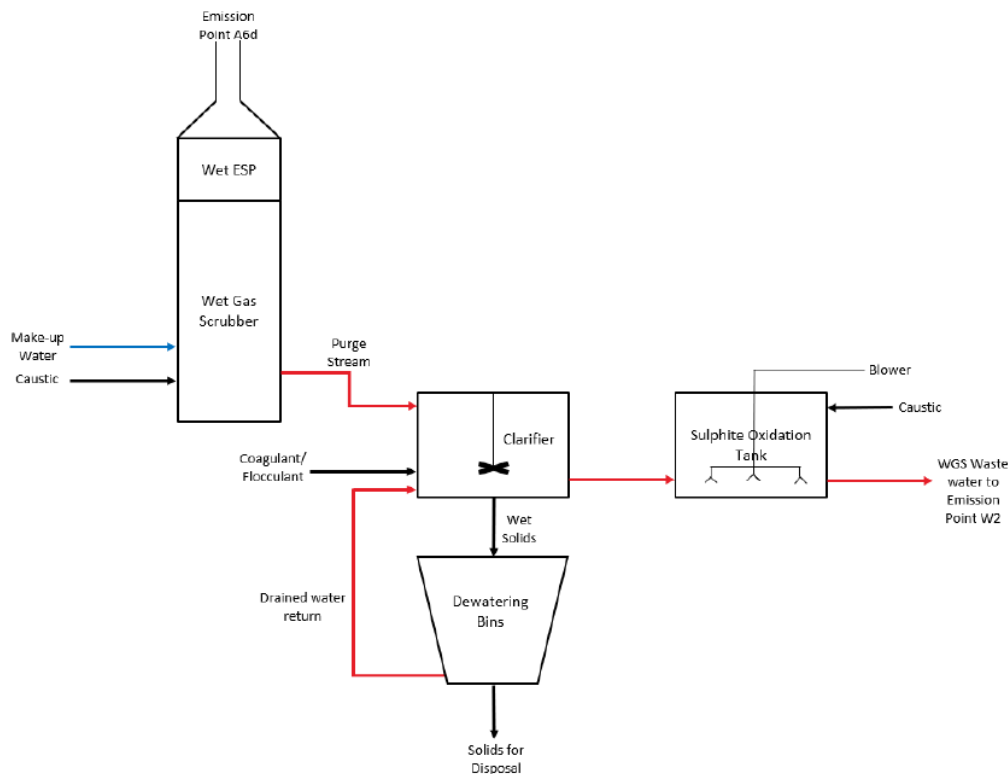
According to the application, there was no information from an existing operational plant that could be used to inform the project on the levels of contaminants that would be present in the purge effluent, as different FCC plants use different feeds, catalysts and additives, so there are no comparable flue gases being treated in existing WGS applications. In addition, the WGS for the PCC Plant application at the installation will treat flue gases to a much higher level than similar plants at other refinery sites, which are only treating flue gases to meet BAT-AELs and not the lower emission levels required for the PCC Plant.

Characterisation of this effluent was therefore undertaken by the applicant based on engineering studies carried out by the WGS equipment vendor. According to these predictions, the main pollutants in this effluent will consist of reduced sulphur species (sulphites) from the removal of SO₂ from the flue gas, requiring oxidation to reduce the chemical oxygen demand (COD) and biological oxygen demand (BOD) of the effluent; particulates associated with the catalyst fines scrubbed from the flue gas; metals associated with these particulates; and ammoniacal nitrogen associated with the dosing of ammonia in the SCR abatement system.

According to the proposal submitted by the applicant, the PTU will include a clarifier which will enable the separation through sedimentation of the suspended solids associated with the catalyst fines, promoted by the addition of coagulant and flocculant. The resulting wet solids will be discharged into dewatering bins below the clarifier, which will hold a membrane to allow the content of the bins to dewater. Liquid drained from the dewatering bins will be collected in a sump and then returned to the clarifier. The dewatered solids will be collected for disposal off-site via a licensed waste contractor.

The liquid level in the clarifier will be maintained with an overflow weir arrangement and the overflowing liquids will be routed to a Sulphite Oxidation Tank. The liquid from the de-watering process will contain ammonium salts and sulphites from the SCR process and the WGS respectively. The Sulphite Oxidation Tank will allow the sulphites present in the liquid to oxidise to sulphates, thereby reducing the Chemical Oxygen Demand (COD) of the liquid effluent. The contents of the Sulphite Oxidation Tank will be recirculated, and caustic (sodium hydroxide) will be dosed into the recirculation loop for pH control. A blower will introduce air bubbles into the contents of the Sulphite Oxidation Tank to aid the oxidation process.

A simplified process flow diagram is reproduced from the 'Application Main Supporting Document' in the following for ease of reference:



According to the information provided by the applicant, the treated wastewater from the PTU will contain sulphates from the removal of SO₂ from the flue gas, ammonia from the SCR and potentially metals (i.e. Nickel, Vanadium, Copper and Iron) due to their presence in the catalyst fines used in the FCC Unit and their potential use in flocculants and coagulants (although the coagulant and flocculant to be used in the PTU will be confirmed during detailed design).

The predicted composition of the PTU effluent is provided in Table 5.3 of the 'Application Main Supporting Document' (document received on application duly made on 18/03/2024), which is referred to for further details. This composition has been used to inform the environmental risk assessment for emissions to water that is discussed in section 2.3.2.

We have reviewed the proposed operating techniques for the proposed PTU and we have compared them against **REF BAT conclusion 12** for removal of insoluble and soluble substances. We have also referred to **BAT conclusion 12** of the BAT conclusions for 'Common waste water and waste gas treatment/ management systems in the chemical sector' (**CWW BAT** conclusions, 2016), that provide a

more comprehensive list of techniques for wastewater treatment relevant to the processing industry.

Based on the information provided, on review, we consider the proposed process stages, when adequately designed, will be a suitable pre-treatment for the WGS purge effluent, effective in removing suspended solids associated with catalyst fines and reducing the COD of the effluent.

However, according to the initial proposal presented in the application ('Application Main Supporting Document') the effluent stream leaving the PTU was proposed to be discharged to the environment through the existing emission point W2 without further treatment, after mixing and dilution with the existing treated effluent generated by the operations of the Humber Refinery. Although the flow rate of the PTU effluent stream is small compared to the existing effluent from the Humber Refinery (i.e. mean flow rate of 0.00154 m³/s for the PTU effluent; compared to 0.10536 m³/s for the existing effluent), we were not satisfied that the initial proposal was compliant with BAT, for the following reasons:

- Despite the WGS purge effluent consisting of high levels of ammoniacal nitrogen, the proposed PTU did not include any treatment to reduce the concentration and loading of this pollutant. The ammoniacal nitrogen loading associated with the WGS purge was therefore proposed to be discharged untreated. The Total Nitrogen predicted by the applicant for the PTU effluent was 191 mg/l, comprised entirely of ammonia, whose levels in the receiving water body are regulated according to the criteria specified in the Water Framework Directive (refer to section 2.3.2 for the environmental risk assessment of discharges to water and a discussion on the applicability of the Water Framework Directive to the recipient surface water body where the discharge takes place). We compared the predicted Total Nitrogen level in the PTU effluent against the BAT-AEL range for Total Nitrogen specified in REF BAT conclusion 12 and associated Table 3, which is much lower (1-25 mg/l). Whilst the BAT-AEL applies to the combined discharge from the installation, we concluded that it was not justified that an effluent stream with such a high nitrogen concentration was not treated at all to reduce this pollutant (and ammonia in particular).
- The main strategy initially proposed by the applicant consisted of dilution of the PTU effluent to attain the final emission levels considered to be consistent with BAT for nitrogen. Whilst dilution might be beneficial, we considered that solely relying on dilution would counteract the BAT principle of preventing or, when not possible, reducing emissions of potentially polluting substances at the source or through adequate treatment.

- Furthermore, we considered that the design of the effluent treatment strategy for the WGS purge resulting in the PTU effluent was affected by high levels of uncertainty warranting a more robust effluent treatment configuration to cope with potential changes to the anticipated effluent composition. This uncertainty was highlighted by the applicant, as they acknowledged that there was no information from an existing operational plant that could be used to inform the project on the levels of contaminants that would be present in the purge effluent; and, in response to our request raised at pre-application stages, they also advised that it was not known whether the sulphite oxidation tank would result in the oxidation of other species too, such as ammoniacal nitrogen to nitrates, elemental metals to metal oxides, etc. and whether this would change the distribution of the oxidised products between the phases (i.e. soluble vs. suspended solids), determining the need for a further solid separation stage downstream of the Sulphite Oxidation Tank, currently not included in the design.

Based on the outcome of our BAT assessment review of the initial proposal, we therefore requested additional information from the applicant in the Schedule 5 Notice served to them on 16/07/2024. The request was aimed at ascertaining further treatment techniques potentially applicable to the PTU wastewater effluent in order to reduce the concentration of ammonia in this effluent and providing more design certainty in relation to attaining or further reducing the concentrations of particulates and metals associated with catalyst fines stipulated in the application.

In their response, received on 29/11/2024, the applicant stated that, although the initial design of the PCC plant did not provide for the PTU wastewater to be treated through the Humber Refinery existing Effluent Treatment Plant (ETP), as it was initially considered that the high sulphate content of the effluent may impact the performance of the existing biological treatment plant, this option was now being considered.

However, this would be subject to carrying out, at the next stage of the project, bench performance tests of a high sulphate effluent to determine whether this would impact on the biological activity of the plant.

We note that at the early stages of the project, when the Environment Agency was involved in pre-application discussions prior to receiving this formal permit application, it was proposed to discontinue the use of the DeSOx additive in the FCCU process; and that this proposal was eventually dismissed in favour of dosing the DeSOx additive to attain a 50% reduction in the SOx levels in the FCCU regenerator flue gas, resulting in turn in a 50% reduction in the sulphur content of the PTU effluent, with the effect of reducing the risks of impairing the biological activity of the existing ETP, when the PTU effluent was to be routed through the ETP to undertake further treatment.

The applicant assessed that, if the tests show that the PTU wastewater could be treated in the existing ETP, this will not result in a reduction in the sulphate content of the PTU wastewater, however it is considered that total organic carbon (TOC), suspended solids and metals concentrations would be reduced, as the PTU wastewater would enter the Oily Water Sewer (OWS) system and therefore be treated through two Induced Air Flotation units (IAF) and the Dissolved Air Flotation unit (DAF), with ammonia and nitrogen concentrations being reduced in the biological treatment plant, which includes nitrification and denitrification stages.

We are satisfied that the approach entailing bench-testing the treatment of the PTU effluent in the ETP is a prudent strategy in the best interests of preventing the unintended deterioration of the performance of the existing ETP and, ultimately, ensuring continued environmental protection in relation to the permitted discharge of the existing effluent generated by the Humber Refinery.

The applicant proposed that, until the outcome of the proposed testing is known, no further consideration of other BAT options would be given to reducing the ammonia, particulates and metals concentrations in the PTU wastewater through dedicated treatment and proposed that further assessment would be carried out only if the testing indicates that the PTU wastewater cannot be treated in the ETP.

We are satisfied that a combination of treatment consisting of the proposed PTU as pre-treatment, followed by further treatment in the existing ETP would be BAT, in that it would address the concerns we raised with the initial proposed design.

In acceptance of the applicant's proposal, we have therefore decided that this process configuration should be considered as the baseline case for the permit variation, and we have specified a pre-operational condition (PO13) requiring the applicant to confirm this is reflected in the final design, taking into account the results of the testing.

If this is not possible, according to the results of the tests, the pre-operational condition (PO13) requires the applicant to assess and propose additional treatment of the PTU stream, upstream of the tie-in point with the combined discharge through emission point W2, in dedicated process equipment aimed at:

- Reduction of ammonia concentration
- Attaining further removal of particulates and metals to cope with the uncertainties of the design inputs and the uncertainties of the effect of the Sulphite Oxidation Tank on the distribution of the oxidised products between the phases.

This assessment shall be informed by any additional / more up to date design data that might emerge throughout the detailed engineering design of the project.

The emission limits at the combined discharge point W2 were already specified to comply with the BAT-AELs stated in the REF BAT conclusions prior to this variation. Refer to section 2.3.2. for the risk assessment of emissions to water and the additional or amended emission limits we have decided to specify at emission point W2 as the result of the change to the environmental risk entailed by this variation.

2.2.2.3 Additional considerations on Integrated Emissions Management Technique and setting emission limits for NOx and SO₂

The existing FCCU at the Humber Refinery operates within the air emissions envelope regulated according to the Integrated Emission Management Technique (IEMT) for emissions of NOx and SO₂, also referred to as the 'refinery bubbles', according to **REF BAT conclusions 57 and 58**.

For ease of reference, we report the relevant excerpts of these BAT conclusions in the following, although we refer to the full text in the BAT conclusions document for further details.

BAT 57. In order to achieve an overall reduction of NOx emissions to air from combustion units and fluid catalytic cracking (FCC) units, BAT is to use an integrated emission management technique as an alternative to applying BAT 24 and BAT 34.

[...]

Table 18 of the REF BAT conclusions specifies:

The BAT-AEL for NOx emissions from the units concerned by BAT 57, expressed in mg/Nm³ as a monthly average value, is equal to or less than the weighted average of the NOx concentrations (expressed in mg/Nm³ as a monthly average) that would be achieved by applying in practice at each of those units techniques that would enable the units concerned to meet the following:

- (a) for catalytic cracking process (regenerator) units: the BAT-AEL range set out in Table 4 (BAT 24);*

[...]

Table 4

BAT-associated emission levels for NO_x emissions to air from the regenerator in the catalytic cracking process

Parameter	Type of unit/combustion mode	BAT-AEL (monthly average) mg/Nm ³
NO _x , expressed as NO ₂	New unit/all combustion mode	< 30-100
	Existing unit/full combustion mode	< 100-300 ⁽¹⁾
	Existing unit/partial combustion mode	100-400 ⁽¹⁾

⁽¹⁾ When antimony (Sb) injection is used for metal passivation, NO_x levels up to 700 mg/Nm³ may occur. The lower end of the range can be achieved by using the SCR technique.

BAT 58. *In order to achieve an overall reduction of SO₂ emissions to air from combustion units, fluid catalytic cracking (FCC) units and waste gas sulphur recovery units, BAT is to use an integrated emission management technique as an alternative to applying BAT 26, BAT 36 and BAT 54.*

[...]

Table 18 of the REF BAT conclusions specifies:

The BAT-AEL for SO₂ emissions from the units concerned by BAT 58, expressed in mg/Nm³ as a monthly average value, is equal to or less than the weighted average of the SO₂ concentrations (expressed in mg/Nm³ as a monthly average) that would be achieved by applying in practice at each of those units techniques that would enable the units concerned to meet the following:

(a) for catalytic cracking process (regenerator) units: the BAT-AEL ranges set out in Table 6 (BAT 26);

[...]

Table 6

BAT-associated emission levels for SO₂ emissions to air from the regenerator in the catalytic cracking process

Parameter	Type of units/mode	BAT-AEL (monthly average) mg/Nm ³
SO ₂	New units	≤ 300
	Existing units/full combustion	< 100-800 ⁽¹⁾
	Existing units/partial combustion	100-1 200 ⁽¹⁾

⁽¹⁾ Where selection of low sulphur (e.g. < 0,5 % w/w) feed (or hydrotreatment) and/or scrubbing is applicable, for all combustion modes: the upper end of the BAT-AEL range is ≤ 600 mg/Nm³.

Prior to this variation, the bubble emission limits at the FCCU regenerator emission point A6b were specified in line with the BAT-AELs set out in tables 4 and 6 of the BAT conclusions as follows:

- Oxides of nitrogen (as NO₂): 300 mg/Nm³
- Sulphur Dioxide: 800 mg/m³ (600 mg/Nm³ when using low sulphur feed (<0.5% w/w sulphur calculated as a monthly average)).

The applicant has opted to continue to include the emissions from the FCCU regeneration process within the refinery NO_x and SO₂ bubbles in the future process configuration, when the flue gases emitted by this process are decarbonised according to activities in the scope of this application.

We have set the following ELVs for the new FCCU regenerator emission point A6d, for the purpose of contributing to the refinery NO₂ and SO₂ bubbles:

Oxides of nitrogen

- **Oxides of nitrogen (as NO₂): 300 mg/Nm³ – monthly average**

We have specified an emission limit, at the top-end of BAT-AEL range for existing unit/full combustion mode plant, for the purpose of calculating the refinery NO_x bubble, subject to the requirement of reducing this ELV according to an improvement condition (IC36) discussed in the following.

Sulphur dioxide

- **Sulphur Dioxide: 600 mg/Nm³ – monthly average**

We have specified an emission limit within the BAT-AEL range for existing unit/full combustion mode plant, for the purpose of calculating the refinery SO₂ bubble. It should be noted that this represents a reduction compared to the currently specified emission limit because, since in the new process configuration the flue gas is scrubbed to remove sulphur species, this value will apply regardless of the concentration of sulphur in the feed, in accordance with note 1 to table 6 of the REF BAT conclusions. As for NO_x, this emission limit will also be subject to the requirement of further reducing this ELV according to an improvement condition (IC36) discussed in the following.

The bubble emission limits will apply to emission point A6d (WGS stack and flue line at the outlet of the WGS process), i.e. to the flue gas prior to decarbonisation. As discussed in item 3.4.2 of the BAT / GET assessment presented in Table 1 of this document, at this stage of the design, the precise location and configuration of the CEMS to emission point A6d (WGS stack) has not been decided yet, and this is subject to a pre-operational condition (PO16). However, in either monitoring options described by the applicant in the application, it will be possible to monitor the flue gas flow rate at a point that

ensures that the flue gas flow rate included in the bubble calculation is not reduced as the consequence of removing the carbon dioxide from the flue gas.

We consider that the future operation of the FCCU in accordance with these emission limits will be compliant with the refinery BAT conclusions and associated BAT-AELs.

However, the operating techniques have changed, and the additional flue gas abatement techniques included in the design will ensure that lower emissions will be attained by the operation of the SCR and wet scrubbing processes, required to meet the flue gas specification at the inlet of the carbon dioxide absorber.

To reflect this reduction, we have specified long term ELVs that will actually cap the emissions of NO_x and SO₂ at the FCCU regenerator stacks. The emission limits that will apply at emission point A6d and A6c are:

- **Oxides of nitrogen (as NO₂): 50 mg/Nm³ – annual average**
- **Sulphur Dioxide: 50 mg/Nm³ – annual average**

These emission limits will apply at the individual stacks and will not be used for the purposes of contributing to the calculation of refinery NO₂ and SO₂ bubbles according to the IEMT.

In deciding the emission limits to specify in the varied permit, we have considered that the additional flue gas abatement introduced by the activities in the scope of this variation is not aimed at attaining compliance with the BAT-AELs or driven by established BAT for the refining activities, but is driven by inlet flue gas specification to prevent degradation of the carbon capture solvent in the absorber column.

We have also considered the information presented by the applicant in the application Main Supporting Document, showing that the inclusion of FCCU regenerator process in the refinery bubble creates headroom for other emissions sources included in the bubble, given that current emissions concentrations from the FCC Unit are already well below the monthly ELVs set out according to the BAT-AELs.

In recognition of the complexity of air emissions management of oil refineries, which include a complex array of combustion and process units interlinked in terms of their feedstock and energy supply and require frequent process adjustments and frequent adjustments of the fuel mix according to process requirements, the REF BAT Conclusions set out a clear intention to provide increased flexibility by implementing the integrated emission management technique, so that NO_x and SO₂ emissions are managed at an integrated level, in such a way that the resulting total emissions are equal to or lower than the emissions that would be achieved through a unit-by-unit application of the BAT-AELs.

Taking into account the aim of the additional abatement processes introduced by this variation and the intention of the integrated management technique, we consider that the implementation of the CCS project should not reduce the flexibility, i.e. the headroom, provided by the current operation of the FCCU regenerator to other combustion units included in the refinery bubbles.

However, at the same time, we consider that the implementation of the integrated management technique in the new process configuration, should not allow for increased flexibility and increased headroom for emissions of NO_x and SO₂ from other refinery combustion units included in the bubbles due to the reduced emissions of NO_x and SO₂ from the FCCU regeneration process attained by the additional flue gas abatement systems.

We therefore consider that it should be possible to reduce the monthly NO_x ELV applicable to the FCC regenerator stack (emission point A6d) from the current top-range BAT-AEL of 300 mg/Nm³, to reflect the reduction of emissions of NO_x introduced by the new SCR system proposed to be fitted to the FCC. The reduction should be in line with the aim of the Integrated Management Technique of reducing the overall emissions of NO_x over time. This reduction will ensure no additional headroom to emit higher levels of NO_x from other refinery combustion or process units included in the NO_x bubble, thanks to the reduction of NO_x emissions achieved by the proposed SCR system in the FCC.

Similarly, although we have already reduced the monthly emission limit for SO₂ applicable to the calculation of the refinery SO₂ bubble to reflect the more stringent BAT-AEL range specified in Table 6 of the REF BAT Conclusions for FCCU processes with wet gas scrubbing, we consider the emission levels attained by this new abatement process should make it possible to further reduce the monthly SO₂ ELV from the current level of 600 mg/m³.

The Application Main Supporting Document recognises that new monthly ELVs should be derived to reflect that the aim of the integrated emission management technique is to reduce overall refinery emissions over time; and that, as such, there should be no increase in the flexibility provided by the bubble limits following introduction of the PCC Plant and the associated reduction in NO_x and SO₂ emissions from the FCC Unit.

In response to the request for further information on the attainable reductions to these emission limits in the Schedule 5 Notice responded on 29/11/2024, the applicant proposed that the reduction of these emission limits is informed by 24 months of monitoring data, based on actual performance of both the refinery and the PCC plant at the time of operation. This is because during the extended time leading to the implementation of the PCC project, the operational set-up of the refinery is likely to change, due to concurrent projects affecting the energy and fuel management of the installation; and because the actual operation SCR and WGS abatement processes should attain lower emission levels than those specified in the design.

We have partially accepted this proposal: we have specified an improvement

condition (IC36) requesting the operator to propose reduced bubble emission limits for NO_x and SO₂ from emission point A6d, informed by emission data gathered from the operation of the FCCU regenerator in the new process configuration, including the abatement introduced by SCR and WGS systems, based on the principle that the bubble headroom should not increase due to the reduced emissions warranted by the operation of these new abatement systems. However, we consider that 18 months of operation will suffice to inform this assessment and that the applicant's proposal to have this assessment based on 24 months of data is unnecessarily long and postpones the reduction of these emission limits beyond the strictly required timeline. We have specified the timeline to respond to this improvement condition as 24 months, including 6 months of time to assess the data and write up the report, in addition to the 18 months required to gather data.

Prior to this variation, Table S3.1a of the permit specified the maximum point source concentration and mass emission limits for Sulphur Dioxide emitted from the combined emission points A6a and A6b (LCP 262 and FCCU regenerator) included in the bubble, as follows:

- SO₂ concentration emission limit: 2000 mg/m³
- SO₂ mass emission limit: 0.33 t/h.

We have amended these emission limits to reflect the future process configuration permitted by this variation.

We have specified in a note to Table S3.1a that the existing emission limits applicable to emission points A6a and A6b will apply until the decommissioning of emission point A6b and its replacement with emission points A6c and A6d as proposed by this variation.

We have specified new point source peak concentration and mass emission limits for Sulphur Dioxide emitted from the new emission point A6d (FCCU Regenerator – WGS stack) which reflect the short-term risk envelope assessed in the application document 'Appendix D – Air Impact Assessment' and confirmed by the Applicant to represent the potential short-term peak emissions during infrequent and time-limited OTNOC scenarios affecting the flue gas desulphurisation in the response to the Schedule Notice received on 29/11/2024 (reference: response to question 3.g.). The new emission limits specified according to this principle are stated in the following:

- **SO₂ concentration emission limit: 600 mg/m³ – hourly average**
- **SO₂ mass emission limit: 0.135 t/h.**

The mass emission limit was calculated by converting the units of measurement of the mass emission rate figure presented in table 4.2 of the application document 'Appendix D – Air Impact Assessment' from grams per second (g/s) to tonnes per hour (t/h): i.e. 37.6 g/s, as: $37.6 \text{ g/s} * 3600 \text{ s/h} * 10^{-6} \text{ t/g}$.

The current permit includes in table S3.3 an annual mass emission limit of 410 tonnes for emissions of sulphur dioxide from the existing FCCU stack, emission

point A6b, that will be decommissioned and replaced by emission points A6c and A6d upon implementation of the proposed PPC project and start-up of the associated activities. We have decided that we don't need to specify an equivalent annual mass emission limit for emissions of sulphur dioxide from the new emission points A6c and A6d, since these emission points are subject to the new annual concentration emission limits discussed above, curbing the annual mass emissions of sulphur dioxide. The specification of a mass emission limit would therefore be redundant in this case.

2.2.2.4 Emission limits and monitoring requirements for carbon capture solvent and its degradation products

We have set emission limits and monitoring requirements in table S3.1 of the variation and consolidation notice for emissions to air of pollutants associated with the use of carbon capture solvent, when the plant is operating in CO₂ abated mode. These limits and monitoring requirements apply to emissions of treated exhaust gases from the PCC absorber stack (new emission point A6c).

This section refers to the outcomes of the air emissions risk assessment that are presented and discussed in section 2.3.1. Please read these two sections in conjunction.

We have set limits for total nitrosamines and nitramines (collectively referred to as N-amines) and total amides and formamides whose impacts do not screen out as insignificant, based on the concentrations used in the modelling of air impacts. This approach is consistent with other carbon capture permits we have issued.

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

Furthermore, the emission limit for ammonia is also specified according to REF BAT conclusion 8, since the flue gas abatement consists of SCR. REF BAT conclusion 4 specifies continuous monitoring of ammonia when SCR is used. Refer to item 3.3.1.2 of Table 1 – BAT / GET assessment for additional details on the BAT assessment in relation to ammonia emissions from the SCR process; and to item 3.4.2 of Table 1 – BAT / GET assessment for additional considerations on the location of the continuous monitoring for ammonia. If continuous monitoring of ammonia is not carried out on the PCC absorber stack (new emission point A6c), periodic monitoring will apply. This approach is consistent with other carbon capture permits.

For some pollutants, whilst the applicant proposed limits based on annual averages, we have set limits based on the 'Average over the sampling period' consistent with other post-combustion carbon capture permits. Annual averages generally apply where continuous monitoring is in place. In the instances where we considered continuous monitoring was not available, as there are currently no certified CEMS for these parameters, we have retained the numerical limits proposed by the applicant and used in the modelling of air impacts, but we have specified them to apply as 'Average over the sampling period'. This is in line with the monitoring requirements specified in our guidance [Monitoring stack emissions: carbon capture plants with solvent-based abatement - GOV.UK](#) that was published during the determination of this variation application.

Table 2 - Emission limits associated with carbon capture solvent performance for emission point A6c

Parameter	Reference Period	Permit limit (mg/m³) Notes 1 and 2
Ammonia	Yearly average or Average over the sampling period ^{Note 6}	5
Total amines ^{Note 3}	Average over the sampling period	1.1
Total N-Amines ^{Note 4}	Average over the sampling period	0.003
Acetaldehyde	Average over the sampling period	0.2
Formaldehyde	Average over the sampling period	0.07
Total amides and formamides ^{Note 5}	Average over the sampling period	0.03

Note 1: No BAT-AELs apply to these parameters, except for ammonia, therefore emission limits reflect the emission concentrations proposed by the Applicant and used in the air quality assessment (AQA) - 'Appendix D – Air Impact Assessment'. 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 O₂ content of 3%. The ammonia BAT-AEL corresponds to the figure modelled in the AQA.

Note 2: Permit limits consistent with those used to assess impacts in table 4-2 of the 'Appendix D – Air Impact Assessment' and in table 6.1 of the Application Main Supporting Document. Also refer to section 2.3.1 of this document.

Note 3: Total amines includes all amines, not just amines 1, 2 and 3 identified by the applicant.

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

Note 5: In the response to Schedule 5 Notice received on 31/03/2025 clarified that the emissions of 'Amides' in the initial application air quality assessment (AQA) - 'Appendix D – Air Impact Assessment' included all the amides and formamides (Amide 1 and 2; Formamide 1 and 2) associated with the degradation of the solvent. We have therefore expressed the emission limit as 'Total amides and formamides'.

Note 6: Only periodic monitoring for ammonia is required at emission point A6c if continuous monitoring is carried out in the flue line between the WGS system and the PCC Plant Absorber. This will be confirmed through a pre-operational condition (PO16). Refer to item 3.4.2 of Table 1 – BAT /

GET assessment for additional considerations on the location of the continuous monitoring for ammonia.

We have specified periodic monitoring requirements for the speciated amines, nitrosamines, amides and formamides; however, we have not considered it necessary to specify individual emission limits for these speciated chemicals as we consider the emission limits specified for each class of these compounds ensures an appropriate level of environmental protection.

The applicant assessed the impacts from acetonitrile, acetone and ethanol which screened out as insignificant. This was provided in their response received 02/10/2024 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 carbon capture permits we have issued. However, we have specified periodic monitoring requirements for these emissions.

The applicant did not assess the impacts from acetate (or the corresponding carboxylic acid, i.e. acetic acid), however it was confirmed as a solvent degradation product in table A2 of the application document 'Appendix D – Air Impact Assessment'. We have not included any limits, consistent with other permits in the sector. The requirements of the linked improvement condition (IC38) will ensure that impacts from acetic acid are assessed with any necessary remedial actions implemented.

2.3 Environmental risk assessment

2.3.1 Emissions to air

The applicant's Air Quality Assessment (AQA) considers the baseline assessment from the existing emissions, together with the emissions from the proposal, i.e. the future assessment. The basis of these assessments is provided in this section (see below).

The AQA explains that there will be two modes of operation, carbon dioxide (CO₂) abated and CO₂ unabated. Normal operation for the installation will be in CO₂ abated mode, when combustion gases are released from the PCC plant absorber stack at emission point A6c. In the unabated mode combustion gases will be released from the WGS at emission point A6d.

The results for modelling of the future scenario CO₂ unabated mode of operation (emissions released at A6d) show worst-case impacts of NO_x, SO₂, CO (carbon monoxide), PM and NH₃, compared to the modelling of the future scenario CO₂ abated mode of operation (emissions released at A6c), and therefore these are reported below for the future assessment.

Assessment methodology

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.

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 **insignificant** 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 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 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 applicant 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.

Assessment of impact on air quality

The applicant's assessment of the impact on air quality is set out in Appendix D - Air Impact Assessment, of the application Main Supporting Document. The assessment comprises:

- baseline and future assessment, as described above and below;
- dispersion modelling of emissions to air and the impact on human health receptors/local air quality from the operation of the PCC plant.
- 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 plant and its impact on local air quality. The impact on conservation sites is considered in section 2.3.1.1 of this document.

The applicant has assessed the potential emissions to air from the PCC plant against the relevant environmental quality standards, and the potential impact upon human health and local conservation sites. These assessments predict the potential effects on local air quality from the PCC plant 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 (NO₂)) 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, as this was considered representative of the likely meteorology at the location 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 these to enable continued compliance with environmental permit requirements;
- the amines and N-amines species likely to be emitted (assumes total N-amines 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.

They also compared current impacts of the emissions from the FCCU stack (i.e. the **baseline assessment**) to the future operation of these emission sources undergoing CO₂ abatement through the PCC plant or unabated operation through the WGS (i.e. the **future assessment**).

Baseline assessment (emission points A6a and A6b)

The **baseline assessment** considered the impact of the existing combustion emissions from the 115m high FCCU stack at emission point A6 on local air quality under normal operating conditions, assuming operation for 8,760 hours per year, as this represents the worst-case for annual average impacts.

Emission point A6 comprises emissions from A6a and A6b:

- Emission point A6a - FCCU feed heater and the isostripper reboiler; and

- Emission point A6b – FCCU regenerator.

The assessment is based on the limits set in the existing permit.

For the modelled emissions, the release rates have been summed for the combined A6 source.

Future assessment (emission points A6c and A6d)

The existing FCCU regenerator emission will vent to the new PCC Plant via a new Selective Catalytic Reduction (SCR) plant and a new Wet Gas Scrubber (WGS) and Wet Electric Precipitator (Wet ESP), which will reduce the combustion emissions of NO₂, SO₂ and particulates from the FCCU regenerator in order to optimise the PCC Plant process, as detailed in sections 2.1 and 2.2 of this document.

There may be times when the PCC Plant is not operational, specifically when the WGS is first commissioned, as this will be prior to the PCC Plant becoming operational, and also potentially before the T&S Network is available. Therefore, the emissions occurring continuously from either the WGS 65m stack (emission point A6d) or the PCC Plant 65m stack (emission point A6c) have both been assessed for the **future assessment**. Emissions will only ever occur from one of these sources at any one time, with the WGS stack only venting emissions when the PCC Plant is not operational.

Only the emissions from the FCC regenerator will be directed to the PCC Plant. The FCC feed heater and the isostripper reboiler will continue to release from the existing FCC unit stack at emission point A6a. As such, the emissions from the existing FCC feed heater and the isostripper reboiler have been modelled from the existing FCC unit stack at the existing release parameters.

For the **future assessment**, due to the addition of the SCR plant and the WGS to reduce the FCC combustion emissions, the concentrations of these pollutants will be lower than the current emission values for the FCC unit stack.

The results for modelling of the WGS future scenario results in worst-case impacts of NO_x, SO₂, CO, PM and NH₃, compared to the modelling of the future scenario PCC Plant absorber emissions, and therefore these are reported below.

Impacts from amines and degradation products are from the PCC Plant absorber emission and are only released from this future scenario source. Emissions associated with the amine solvent are based on concentrations provided by the technology provider.

The applicant provided us with the 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 audited 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 sections below.

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

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 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 table 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.

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

Current permit baseline – maximum at a human health receptor			
Pollutant	EQS/EAL ($\mu\text{g}/\text{m}^3$)	PC ($\mu\text{g}/\text{m}^3$)	PC as % of EQS/EAL
Nitrogen dioxide (NO ₂) Annual mean	40	0.33	0.83
NO ₂ 1 hour mean	200	3.9	1.95
Carbon monoxide (CO) 1 hour mean	30,000	11.4	0.04
CO 8 hour mean	10,000	7.2	0.07
Particulate matter (PM ₁₀) Note 1	40	0.06	0.15

Current permit baseline – maximum at a human health receptor			
Pollutant	EQS/EAL ($\mu\text{g}/\text{m}^3$)	PC ($\mu\text{g}/\text{m}^3$)	PC as % of EQS/EAL
Annual mean			
PM ₁₀ ^{Note 1} 24 hour mean	50	0.2	0.40
PM _{2.5} ^{Note 2} Annual	20	0.06	0.30
Sulphur dioxide (SO ₂) 15 minute mean	266	24.2	9.09
SO ₂ 1 hour mean	350	20.2	5.77
SO ₂ 24 hour mean	125	6.5	5.20
Ammonia (NH ₃) Annual mean	180	0.02	0.01
NH ₃ 1 hour mean	2,500	0.6	0.02
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).

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

Future – maximum at a human health receptor						
Pollutant	EQS/EAL ($\mu\text{g}/\text{m}^3$)	PC ($\mu\text{g}/\text{m}^3$)	PC as % of EQS/EAL	PEC ($\mu\text{g}/\text{m}^3$) (Background + PC)	PEC as % of EQS/EAL	Change in PC over baseline %
NO ₂ Annual mean	40	0.2	0.50	-	-	-0.3
NO ₂ 1 hour mean	200	18.6	9.30	-	-	+7.3
CO 1 hour mean	30,000	21.9	0.07	-	-	0
CO 8 hour mean	10,000	15.1	0.15	-	-	+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/EAL	Change in PC over baseline %
PM ₁₀ ^{Note 1} Annual mean	40	0.05	0.13	-	-	0
PM ₁₀ ^{Note 1} 24 hour mean	50	0.23	0.46	-	-	+0.1
PM _{2.5} ^{Note 2} Annual	20	0.05	0.25	-	-	0
SO ₂ 15 minute mean	266	124.6	46.84	131.40	49.39	+37.7
SO ₂ 1 hour mean	350	106.2	30.34	113	32.29	+24.5
SO ₂ 24 hour mean	125	38.3	30.64	41.70	33.36	+25.5
NH ₃ Annual mean	180	0.03	0.02	-	-	+0.01
NH ₃ 1 hour mean	2,500	1.0	0.04	-	-	+0.02
Amine 1 ^{Note 6} and 3 ^{Note 8} 24 hour mean	100 ^{Notes 4 and 9}	0.05	0.05	-	-	-
Amine 1 ^{Note 6} and 3 ^{Note 8} Hourly mean	400 ^{Note 9}	0.16	0.04	-	-	-
Amine 2 ^{Note 7} 24 hour mean	17 ^{Notes 3 and 9}	0.006	0.04	-	-	-
Amine 2 ^{Note 7} Hourly mean	75 ^{Notes 3 and 9}	0.018	0.02	-	-	-
Piperazine (Amine 2 ^{Note 7}) 24 hour mean	15 ^{Note 3}	0.006	0.04	-	-	-
Amine 1 ^{Note 6} + Amine 2 ^{Note 7} + Amine 3 ^{Note 8} 24 hour mean	15	0.05 +0.006 = 0.06	0.37	-	-	-

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/EAL	Change in PC over baseline %
Acetaldehyde Annual mean	370	0.00069	0.0002	-	-	-
Acetaldehyde 1 hour mean	9,200	0.03	0.0003	-	-	-
Formaldehyde Annual mean	5	0.00024	0.005	-	-	-
Formaldehyde 30 minute mean	100	0.011	0.011	-	-	-
Amide Annual mean	0.05 ^{Note 5}	0.0001	0.2	-	-	-
Amide Hourly mean	18 ^{Note 5}	0.0047	0.03	-	-	-
<p>Note 1: Particles of 10 microns and smaller.</p> <p>Note 2: Particles of 2.5 microns and smaller.</p> <p>Note 3: Refer to Environment Agency assessment conclusions below.</p> <p>Note 4: If we apply the much lower EAL for piperazine, the emission still screens out as insignificant with the PC 0.33% of the EAL.</p> <p>Note 5: See below for the justification for the use of the acrylamide EAL for the assessment of amides.</p> <p>Note 6: Amine 1 - 1-Piperazineethanol</p> <p>Note 7: Amine 2 - Piperazine</p> <p>Note 8: Amine 3 - 1,4-Piperazinediethanol</p> <p>Note 9: EAL derived proposed by the Applicant but not endorsed by the Environment Agency. Refer to the Environment Agency assessment conclusions below for additional details.</p>						

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 SO₂.

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.

SO₂ emissions (which were not screened out as insignificant) have been assessed as being unlikely to give rise to significant pollution in that the PEC is less than 100% of the environmental quality standard (taking expected modelling uncertainties into account). We have carefully scrutinised the applicant's proposals to ensure that they are applying BAT to prevent and minimise SO₂ emissions. This is reported in section 2.2.1 of this document (sub-section 3.3.1 'Flue gas cleaning' of Table 1 – 'BAT/GET assessment').

For NO₂, the change in PC over the baseline assessment is -0.3% and +7.3% respectively, for the long and short-term assessments, however the PC will remain insignificant according to our screening criteria.

For SO₂, the change in PC over the baseline assessment ranges from 24.5% to 37.7%.

Due to modelling the NO_x and SO₂ impacts at the monthly BRef Bubble limits for short-term impacts, there is a predicted increase in these impacts. However, the FCCU cannot operate without the WGS and SCR being operational, and therefore these higher emission concentrations will never actually occur in practice. Even at these higher emission concentrations, the predicted impacts at human health receptors are insignificant in the case of NO_x, or not predicted to result in an exceedance of the EQS in the case of SO₂.

Total amides were assessed against the EAL for acrylamide. 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. They therefore considered that the use of the acrylamide EAL was very conservative.

Environment Agency assessment conclusions

We consider that contributions from the proposed variation are unlikely to be significant or be the cause of an exceedance of the environmental standards.

Our checks indicate that:

- the applicant's 15 min SO₂ degree of change in PCs are not insignificant at receptor locations (up to 37.7%, indicatively); and
- background values selected by the applicant under-represent short-term SO₂ exposure.

However, we note that the short-term impacts were modelled at an emission level of 600 mg/Nm³, whilst the use of the WGS technology will attain a concentration of SO₂ of less than 50 mg/Nm³. As discussed in section 2.2.2.3, this figure has been specified as an annual average emission limit for emission points A6c and A6d. Whilst short-term emissions might occasionally be higher, in order to comply with the annual emission limit, these emissions will need to be at or below 50 mg/Nm³ for most of the operating hours in a calendar year. Furthermore, in response to the Schedule 5 Notice issued on 16/07/2024, the applicant confirmed

that in the case of malfunctioning of the WGS abatement technology, the maximum theoretical concentration of SO₂ expected to be emitted by the FCCU unit with use of DeSO_x additive is approximately 480 mg/Nm³, well below the modelled input of 600 mg/Nm³. According to the information provided by the applicant, we therefore consider that the predicted short-term SO₂ PC and PEC are very conservative and reflect a worst-case scenario that might only happen in the case of OTNOC.

We therefore don't expect the short-term SO₂ PC to cause exceedances of the environmental standards. In fact, our calculations indicate that they would actually be screened out as insignificant (i.e. 15 minute mean $50/600 * 124.6 \mu\text{g}/\text{m}^3 = 10.4 \mu\text{g}/\text{m}^3$ (4% of the EAL) and 1 hour mean $50/600 * 106.2 \mu\text{g}/\text{m}^3 = 8.85 \mu\text{g}/\text{m}^3$ (2.5% of the EAL)).

The applicant's model is based on direct amine emissions of amine 1 and amine 3 at 0.05 mg/Nm³, and amine 2 at 0.0055 mg/Nm³. These levels were advised by the solvent provider based on a "proprietary amine emissions model", however, they have not provided supporting evidence. Our audit is based on these emission levels.

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 and derived their own EALs. The applicant's derived 24-hour annual mean EAL is 17 $\mu\text{g}/\text{m}^3$ and the 100th percentile 1-hour mean EAL is 75 $\mu\text{g}/\text{m}^3$.

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 section 4.1.1 of this document for UKHSA comments on this matter.

Working with the UKHSA, we have derived a long-term EAL for piperazine of 0.015 mg/m³ (15 $\mu\text{g}/\text{m}^3$) 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.

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 $\mu\text{g}/\text{m}^3$ is not that dissimilar from the one proposed by the Applicant for amine 2 of 17 $\mu\text{g}/\text{m}^3$, 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.

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), the UKHSA 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 (IC38) requiring the Operator to compare actual emissions from the PCC plant 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 (IC31) to report on the performance testing of the PCC plant including a summary of the environmental performance of the PCC plant as installed against the design parameters and risk assessments.

We asked the applicant to justify the exclusion of acetonitrile, ethanol and acetone from their assessment. They confirmed that 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 $\mu\text{g}/\text{m}^3$ and 370 $\mu\text{g}/\text{m}^3$ for hourly and annual impacts respectively).

They also confirmed that 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 a lower EAL of 47 $\mu\text{g}/\text{m}^3$.

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 operation of the absorber column.

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. The applicant 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 \(ukccsrc.ac.uk\)](https://ukccsrc.ac.uk/AQMAU-C2025-RP01.pdf) 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 \(www.gov.uk\)](https://www.gov.uk/guidance/air-emissions-risk-assessment-for-your-environmental-permit) [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 Monoethanolamine (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 16/07/2024 (additional information requested 26/02/2025), the applicant provided an updated N-amine assessment. The N-amines assessment was updated using the 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 D of the Main Supporting Document.

The following tables show the maximum predicted PCs at receptor R8, 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/m³)	Nitrosamine 1 PC (ng/m³)	Nitramine 1 PC (ng/m³)	Total N- amines 1^{Note 1} PC (ng/m³)	Total N- amines 1 PC as % of EAL
NDMA Annual mean	0.2	0.021	0.013	0.034	17
Note 1: 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 within the very conservative EAL for NDMA. The worst-case impacts are at receptor R8 and represent 17% of the NDMA 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/m ³)	Nitrosamine 2 PC (ng/m ³)	Nitramine 2 PC (ng/m ³)	Total N- amines 2 ^{Note 1} PC (ng/m ³)	Total N- amines 2 PC as % of EAL
NDMA Annual mean	0.2	0.005	0.002	0.007	4
Note 1: 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 at receptor R8 and represent 4% of the NDMA 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/m ³)	Nitrosamine PC (ng/m ³)	Nitramine PC (ng/m ³)	Total N- amines PC (ng/m ³)	PC as % of AQAL
NDMA Annual mean	0.2	0.026	0.015	0.041	21

The results for the total N-amine impacts for the future operation of the Installation indicates that PCs at receptor locations are within the conservative EAL for NDMA. The worst-case impacts are at receptor R8 and represent 21% of the NDMA 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 Phillips 66 Humber Refinery (this project) and the adjacent VPI Immingham CHP Power Plant.

We asked the applicant to provide a cumulative assessment of emissions of nitrosamines, taking into account the nearby proposed VPI 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 request for further information dated 16/07/2024 (additional information requested 26/02/2025), and is summarised below:

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

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

Section 6.3.3 of Appendix D 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 Phillips 66 and VPI 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 the two worst affected discrete receptors (R2 and R8) of the releases of atmospheric N-amines (from Phillips 66 and VPI) 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 human health receptors					
Pollutant	EAL (ng/m ³)	Total Phillips 66 N-amines PC (ng/m ³)	Total VPI N- amines PC (ng/m ³)	Cumulative N-amines PC (ng/m ³)	Cumulative N-amines PC as % of EAL
NDMA	0.2	0.019	0.134	0.153	77 Note 1
Annual mean		0.041	0.113	0.154	77 Note 2
Note 1: R2 receptor, unoccupied residence, understood to be being demolished.					
Note 2: R8 receptor.					

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 D 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.

Environment Agency assessment conclusions

Amine 1 and amine 2 are secondary amines and can potentially form stable nitrosamines and nitramines (referred to as '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. 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 must be via a different mechanism and there is limited published data for tertiary amine reaction constants. As amine 3 makes up 0.4% of the total modelled emission concentration of amine 1, possible nitrosamines formed would make up a small quantity of the total N-amines. Given the low proportion of amine 3 released from the stack, we accept the Applicant's approach.

At the time of our audit, there were no EALs for any of 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 compared with the NDMA EAL. As a result, they state that the NDMA EAL would serve as a "very conservative" EAL for the N-amines from amine 1 and amine 2. These form the basis of our decision-making. Refer to section 4.1.1 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 Phillips 66 alone is 21% 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 2.2.1 of this document.

We have included an improvement condition (IC38) requiring the operator to compare actual emissions from the PCC plant with those provided with the Application and if necessary to carry out an impact assessment.

We have also set an improvement condition (IC31) 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.

Future – H1 screening assessment of metals

The applicant confirmed that the existing particulate limit of 50 mg/Nm³ is anticipated to reduce to below 10 mg/Nm³. This will therefore correspondingly result in a significant reduction in the metals concentrations in the emissions to air from the WGS/CO₂ absorber stacks.

The applicant reviewed analysis carried out on the catalyst fines over 15 months. The relevant proportions of antimony, copper, nickel and vanadium were determined and applied to the proposed future limit of 10 mg/Nm³ to determine the future concentrations of the relevant metals in the WGS/CO₂ absorber emissions.

The calculated emission concentrations were assessed using our H1 screening tool to determine whether there are likely to be any environmental impacts associated with the metal emissions from the new stacks. The impacts from the worst case WGS scenario are presented in the table below.

Future – Point of maximum impact					
Pollutant	EQS/EAL ($\mu\text{g}/\text{m}^3$)	PC ($\mu\text{g}/\text{m}^3$)	PC as % of EQS/EAL	PEC ($\mu\text{g}/\text{m}^3$) (Background + PC)	PEC as % of EQS/EAL
Antimony Annual mean	5	0.0000299	0.000598	-	-
Antimony 1 hour mean	150	0.0011	0.000733	-	-
Copper 24 hour mean	0.05	0.00004140	0.0828	-	-
Nickel Annual mean	0.02	0.00157	7.85	0.00287	14.35
Nickel 1 hour mean	0.7	0.0572	8.17	-	-
Vanadium 24 hour mean	1	0.135	13.5	0.1388	13.88

Stage 1 screening assessment

Antimony and copper are screened out as insignificant, with PCs that are less than 1% of the annual mean and 24 hour mean (long-term) EAL and less than 10% of the EAL for the 1 hour mean (short-term).

Stage 2 screening assessment

Nickel and vanadium are screened out at the second stage of screening from requiring further assessment through dispersion modelling:

- the nickel PEC is less than 70% of the annual mean (long-term) environmental standard; and
- the vanadium PC is less than 20% of the 24 hour mean (short-term) environmental standard minus twice the long-term background concentration.

Whilst nickel and vanadium are not screened out as insignificant, they were assessed as being unlikely to give rise to significant pollution.

Environment Agency assessment conclusions

The installation has been assessed as meeting BAT for control of emissions of particulates to air, refer to section 2.2.1 of this document.

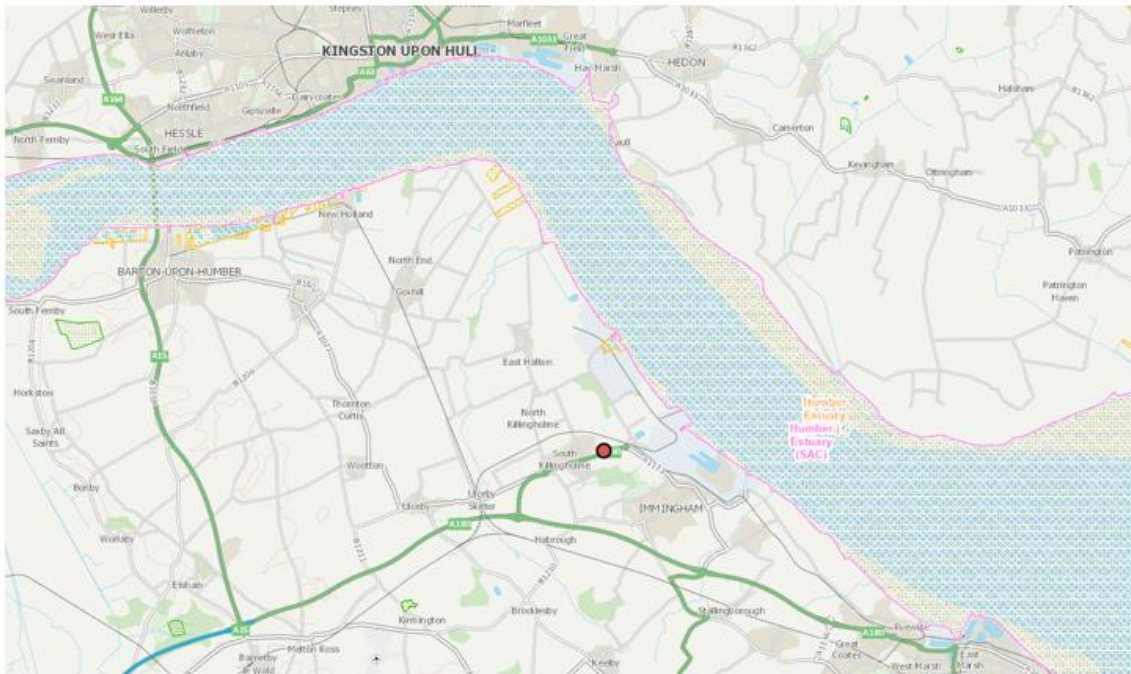
We agree with the applicant's numerical predictions and conclusions.

2.3.1.1 Impact on habitats sites, SSSIs and non-statutory conservation sites

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:

- Humber Estuary

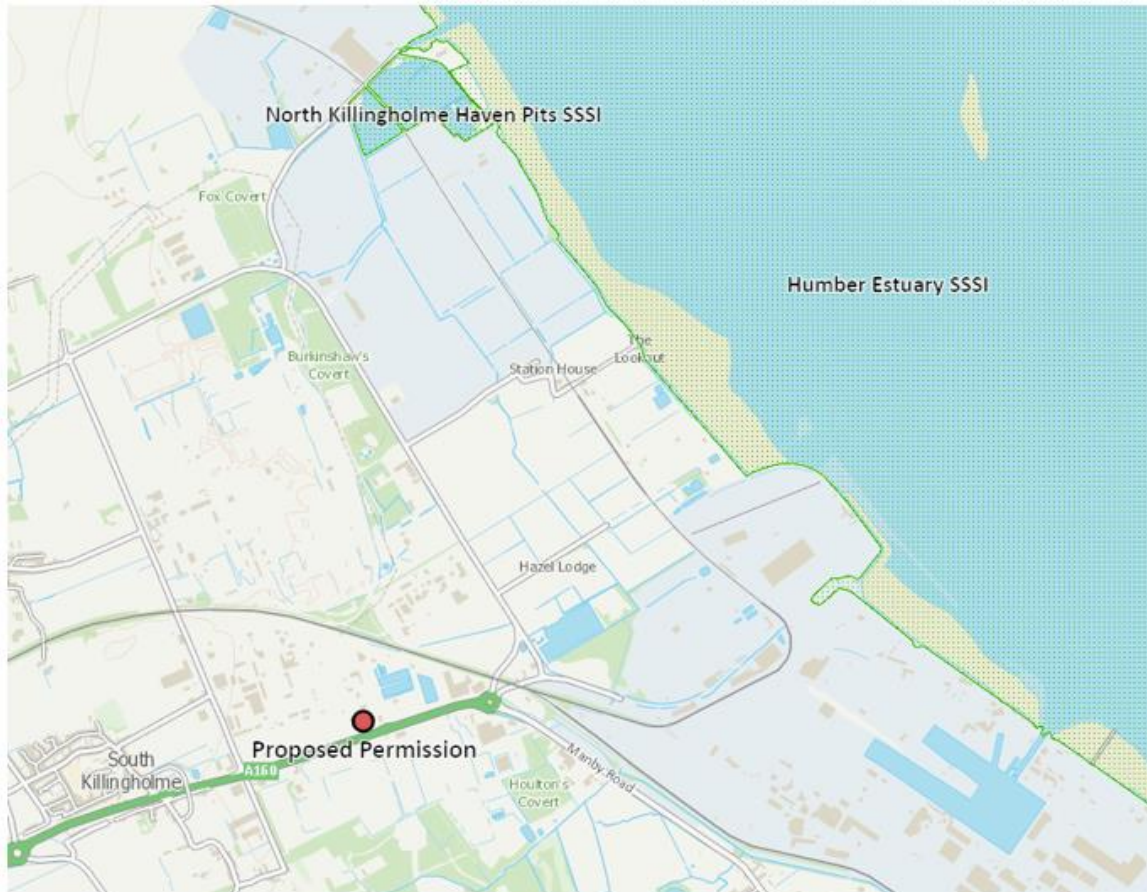


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-  Ramsar
-  Special Area of Conservation (SAC)
-  Special Protection Area (SPA)
-  Marine Conservation Zone (MCZ)
-  PPP location

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

- Humber Estuary
- North Killingholme Haven Pits



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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
- Burkinshaws Covert LWS
- Rosper Road Pools LWS
- Chase Hill Wood LWS
- Mayflower Wood Meadow LWS
- Homestead Park Pond LWS / SINC
- Eastfield Road Pit SINC

Habitats assessment

The following details the results of the applicant's air quality modelling assessment on the Humber Estuary:

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

Baseline – maximum at the Humber Estuary						
Pollutant	EQS/EAL ($\mu\text{g}/\text{m}^3$)	Back- ground ($\mu\text{g}/\text{m}^3$)	PC ($\mu\text{g}/\text{m}^3$)	PC as % of EQS/EAL	PEC ($\mu\text{g}/\text{m}^3$)	PEC
Direct Impacts ^{Note 1}						
NO _x Annual mean	30	20	0.48	1.6	20.48	68.27
NO _x Daily mean	75	-	3.1	4.13	-	-
SO ₂ Annual mean	20	3.2	0.9	4.5	4.1	20.5
NH ₃ Annual mean	3	-	0.02	0.67	-	-
Deposition Impacts ^{Note 1}						
Nitrogen deposition (kg N/ha/yr) Annual mean	10	17	0.14	1.36	17.14	171.36
Acid deposition (Keq/ha/yr) Annual mean	No critical load assigned in APIS ^{Note 2}	-	-	-	-	-
Note 1: Direct impact units are $\mu\text{g}/\text{m}^3$ 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 the Air Pollution Information System (APIS).						

NO_x (annual)

The PEC is under the 70% threshold and therefore can be considered to be not significant. The applicant noted that the background concentration already includes the existing contribution from the installation, and therefore it is considered that the actual PEC will be below this value.

NO_x (daily mean)

Emissions screen out as insignificant (PC is <10% of the short-term EQS/EAL).

SO₂

The PEC is under the 70% threshold and therefore can be considered to be not significant. The applicant noted that the background concentration already includes the existing contribution from the installation, and therefore it is considered that the actual PEC will be below this value.

NH₃

Emissions screen out as insignificant (PC is <1% of the long-term EQS/EAL).

Nitrogen deposition

The nitrogen deposition PC is not insignificant, and the PEC exceeds the critical load due to the elevated background deposition. Refer to our assessment below.

Acid deposition

There are no associated critical loads for acid deposition.

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	-	0.22	0.73	-	-	-0.9
NO _x Daily	75	-	6.1	8.13	-	-	+4.2

Future – maximum at the Humber Estuary							
Pollutant	EQS/EAL ($\mu\text{g}/\text{m}^3$)	Back-ground ($\mu\text{g}/\text{m}^3$)	PC ($\mu\text{g}/\text{m}^3$)	PC as % of EQS/EAL	PEC ($\mu\text{g}/\text{m}^3$)	PEC as % EQS/EAL	Change in PC over baseline %
mean							
SO ₂ Annual mean	20	-	0.19	0.95	-	-	-3.5
NH ₃ Annual mean	3	-	0.018	0.6	-	-	+0.1
Deposition Impacts ^{Note 1}							
Nitrogen deposition (kg N/ha/yr) Annual mean	10	17	0.13	1.3	17.13	171.3	-0.1
Acid deposition (Keq/ha/yr) Annual mean	No critical load assigned in APIS <small>Note 2</small>	-	-	-	-	-	-
<p>Note 1: Direct impact units are $\mu\text{g}/\text{m}^3$ and deposition impact units are kg N/ha/yr or Keq/ha/yr.</p> <p>Note 2: For acidification, there is no critical load assigned to the Humber Estuary in the Air Pollution Information System (APIS).</p>							

NO_x (annual/daily mean)

Emissions screen out as insignificant (PC is <1% of the long-term and <10% of the short-term EQS/EAL).

The change in PC over the baseline assessment is -0.9% (annual) and +4.2% (daily).

SO₂

Emissions screen out as insignificant (PC is <1% of the long-term EQS/EAL).

The change in PC over the baseline assessment is -3.5%.

NH₃

Emissions screen out as insignificant (PC is <1% of the long-term EQS/EAL).

The change in PC over the baseline assessment is +0.1%.

Nitrogen deposition

The nitrogen deposition PC is not insignificant, and the PEC exceeds the critical load due to the elevated background deposition. Nitrogen deposition includes nitrogen from amines and their degradation products. Refer to our assessment below.

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 plant 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.

In any event, the change in PC over the baseline assessment is -0.1%.

Acid deposition

There are no associated critical loads for acid deposition. In any event, the emissions from the site that would contribute to acid deposition are not significantly changing from the current emission scenario; and critical levels which are generally protective of critical loads (NO_x/SO₂/NH₃) have all screened out as insignificant.

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).

A copy of the stage 1 and stage 2 HRA assessment and Natural England's response are available to view on our public register.

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.

We reviewed the applicant's habitats assessment and agree with the conclusions, that there would be no likely significant effect on the interest features of the protected sites.

Regarding in-combination impacts, we note that the adjacent VPI Immingham site makes the majority of the contributions towards the nutrient nitrogen deposition critical loads.

Our checks indicate that PCs, or changes in PCs are below 1% and 10% of the relevant critical levels and loads.

For acidification we can conclude that there is no effect at all from the proposal.

With the exception of nutrient nitrogen deposition, all emissions to air from this proposal screened out under the significance criteria. We recorded this on our stage 1 Habitats Risk Assessment (HRA) form. Nutrient nitrogen deposition was taken to the appropriate assessment stage. We completed the stage 2 HRA to determine if the impacts would have an adverse impact on the habitat site.

We concluded that:

There are several mitigating factors to consider however:

- The proposal to install carbon capture at the site will reduce emissions from the site overall including long-term NO_x and SO₂ and nitrogen deposition.
- In unit 94 the saltmarsh is in favourable condition suggesting it is not adversely affected by the high historical background nutrient nitrogen deposition. The unfavourable status for unit 95 is not associated with nutrient nitrogen deposition but instead, according to a site assessment in 2018, it is due to coastal erosion.
- In this 2018 site assessment of units 94 and 95 Natural England comments are as follows *'Condition is assessed with reference to baseline at designation. Targets passed: total extent of saltmarsh/ intertidal reedbed and swamp; invertebrate habitat; absence of undesirable plant species; absence of other negative factors - **including pollution** (excluding inorganic tidal debris), poaching, new drainage, physical damage, increase in bare substrate as a result of anthropogenic activities such as vehicle use or trampling at vulnerable locations; species composition of vegetation communities; zonation of vegetation. This is not a grazed unit so sward height is not applicable. Targets failed: loss of*

Atlantic salt meadow SAC community due to erosion; Spartina cover >5% (non-mandatory)'. This suggests the saltmarsh in units 95 and 94 (and SAC/SPA/Ramsar) are not being adversely affected by the high background nutrient nitrogen deposition which also appears to have been high(er) in 2018.

- North Killingholme Haven Pits SSSI and the overlying Humber Estuary SPA is divided into two areas/units. Unit 1, the closest to the proposed facility is in favourable condition, unit 2 is in unfavourable condition. These condition assessments were undertaken in 2018 and appear to be focused around three targets regarding area of open water, water depth and salinity. No reference is made to nutrient pollution which again appears to have been high in 2018, and likely means that no adverse impacts were occurring.

Given the age of the last site survey carried out by Natural England, we have consulted with them on the potential impacts highlighted above. If the saltmarsh was now in favourable condition, it would provide further evidence that the high background nutrient deposition was not having an adverse effect.

Due to the mitigating factors above, conservative nature of modelling and the slight reduction in nutrient nitrogen deposition, we conclude that there will be no adverse effect on the designated site and its features. We have consulted with Natural England, see below.

We also assessed in-combination impacts from permit applications within 15km, both live and issued, since the background APIS information was collected. We also checked north Lincolnshire and north-east Lincolnshire planning portals and no other relevant planning applications were found.

The key development to consider in combination was the EPR/BJ8022IZ/V014 VPI Immingham carbon capture Application. The applicant modelled the potential cumulative impact of these two sites and found that it does not substantially change the PEC. The PEC increases from 171% to 175% of the EQS/EAL.

We conclude that if Natural England agree that the mitigation factors outlined in the alone assessment are sufficient to conclude no adverse effect then they can also be sufficient for the in-combination assessment. We therefore conclude no adverse effect in combination and have consulted with Natural England, see below.

We sent the stage 1 and 2 HRA to Natural England for consultation and they responded as follows:

In view of the European site's conservation objectives, and taking account of the mitigating measures either included in the proposal and/or to be imposed by your authority to avoid harmful effects on the site, Natural England concurs with the reasoning and the conclusions of the appropriate assessment that the plan or project will not adversely affect the integrity of the Humber Estuary

SPA/SAC/Ramsar subject to the conditions proposed. Therefore, and subject to the proposals being carried out in strict accordance with the details submitted (including any conditions to be attached to the permission), we advise you, as the Competent Authority, that it can be ascertained that this application will not adversely affect the integrity of the Humber Estuary SAC/SPA/Ramsar.

SSSI Assessment

The following details the results of the applicant's air quality modelling assessment on the North Killingholme Haven Pits, which is the most impacted SSSI:

Baseline - The modelling predicted maximum pollutant concentrations at the North Killingholme Haven Pits receptor

Baseline – maximum at the North Killingholme Haven Pits						
Pollutant	EQS/EAL L ($\mu\text{g}/\text{m}^3$)	Back-ground ($\mu\text{g}/\text{m}^3$)	PC ($\mu\text{g}/\text{m}^3$)	PC as % of EQS/EAL	PEC ($\mu\text{g}/\text{m}^3$)	PEC as % EQS/EAL
Direct Impacts <small>Note 1</small>						
NO _x Annual mean	30	18	0.5	1.67	18.5	61.67
NO _x Daily mean	75	-	3.3	4.4	-	-
SO ₂ Annual mean	20	3.4	0.92	4.6	4.32	21.6
NH ₃ Annual mean	3	-	0.02	0.67	-	-
Deposition Impacts <small>Note 1</small>						

Baseline – maximum at the North Killingholme Haven Pits						
Pollutant	EQS/EAL L ($\mu\text{g}/\text{m}^3$)	Back-ground ($\mu\text{g}/\text{m}^3$)	PC ($\mu\text{g}/\text{m}^3$)	PC as % of EQS/EAL	PEC ($\mu\text{g}/\text{m}^3$)	PEC as % EQS/EAL
Nitrogen deposition (kg N/ha/yr) Annual mean	10	17	0.14	1.36	17.14	171.36
Acid deposition (Keq/ha/yr) Annual mean	No critical load assigned in APIS Note 2	-	-	-	-	-
Note 1: Direct impact units are $\mu\text{g}/\text{m}^3$ 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 North Killingholme Haven Pits in the Air Pollution Information System (APIS).						

NOx (annual)

The PEC is under the 70% threshold and therefore can be considered to be not significant. The Applicant noted that the background concentration already includes the existing contribution from the Installation, and therefore it is considered that the actual PEC will be below this value.

NOx (daily mean)

Emissions screen out as insignificant (PC is <10% of the short-term EQS/EAL).

SO₂

The PEC is under the 70% threshold and therefore can be considered to be not significant. The Applicant noted that the background concentration already includes the existing contribution from the Installation, and therefore it is considered that the actual PEC will be below this value.

NH₃

Emissions screen out as insignificant (PC is <1% of the long-term EQS/EAL).

Nitrogen deposition

The nitrogen deposition PC is not insignificant, and the PEC exceeds the critical load due to the elevated background deposition. Refer to our assessment below.

Acid deposition

There are no associated critical loads for acid deposition.

Future - The modelling predicted maximum pollutant concentrations at the North Killingholme Haven Pits receptor

Future – maximum at the North Killingholme Haven Pits							
Pollutant	EQS/EAL ($\mu\text{g}/\text{m}^3$)	Back-ground ($\mu\text{g}/\text{m}^3$)	PC ($\mu\text{g}/\text{m}^3$)	PC as % of EQS/EAL	PEC ($\mu\text{g}/\text{m}^3$)	PEC as % EQS/EAL	Change in PC over baseline %
Direct Impacts ^{Note 1}							
NO _x Annual mean	30	-	0.25	0.83	-	-	-0.8
NO _x Daily mean	75	-	6.5	8.67	-	-	+4.3
SO ₂ Annual mean	20	3.4	0.22	1.1	3.62	18.1	-3.5
NH ₃ Annual mean	3	-	0.02	0.67	-	-	+0.1
Deposition Impacts ^{Note 1}							
Nitrogen deposition (kg N/ha/yr) Annual mean	10	17	0.13	1.3	17.13	171.3	-0.1
Acid deposition (Keq/ha/yr) Annual mean	No critical load assigned in APIS ^{Note 2}	-	-	-	-	-	-
Note 1: Direct impact units are $\mu\text{g}/\text{m}^3$ and deposition impact units are kg N/ha/yr or							

Future – maximum at the North Killingholme Haven Pits							
Pollutant	EQS/EAL ($\mu\text{g}/\text{m}^3$)	Back-ground ($\mu\text{g}/\text{m}^3$)	PC ($\mu\text{g}/\text{m}^3$)	PC as % of EQS/EAL	PEC ($\mu\text{g}/\text{m}^3$)	PEC as % EQS/EAL	Change in PC over baseline %
Keq/ha/yr.							
Note 2: For acidification, there is no critical load assigned to the North Killingholme Haven Pits in the Air Pollution Information System (APIS).							

NO_x (annual/daily mean)

Emissions screen out as insignificant (PC is <1% of the long-term and <10% of the short-term EQS/EAL).

The change in PC over the baseline assessment is -0.8% (annual) and +4.3% (daily).

SO₂

The PEC is under the 70% threshold and therefore can be considered to be not significant. The Applicant noted that the background concentration already includes the existing contribution from the Installation, and therefore it is considered that the actual PEC will be below this value.

The change in PC over the baseline assessment is -3.5%.

NH₃

Emissions screen out as insignificant (PC is <1% of the long-term EQS/EAL).

The change in PC over the baseline assessment is +0.1%.

Nitrogen deposition

The nitrogen deposition PC is not insignificant, and the PEC exceeds the critical load due to the elevated background deposition. Refer to our assessment below.

The change in PC over the baseline assessment is -0.1%.

Acid deposition

There are no associated critical loads for acid deposition. In any event, the emissions from the site that would contribute to acid deposition are not significantly changing from the current emission scenario; and critical levels which are generally protective of critical loads (NO_x/SO₂/NH₃) have screened out or have significant headroom.

Environment Agency assessment

We reviewed the applicant's SSSI assessment and agree with the conclusions, that the proposal would not damage the special features of the SSSI. This was recorded on a CROW (Countryside and Rights of Way Act 2000), Appendix 4 form.

A copy of the Appendix 4 CROW assessment and Natural England's response are available to view on our public register.

Our checks indicate that PCs or changes in PCs are below 1% and 10% of the relevant critical levels and loads.

For acidification we can conclude that the proposal is not likely to damage any of the designated features associated with the SSSIs.

With the exception of nutrient nitrogen deposition, all emissions to air from this proposal screened out under the significance criteria or the PEC was below 100% of the EQS/EAL. For nutrient nitrogen deposition the PEC is above 100%, suggesting that damage may occur.

We concluded that:

There are several mitigating factors to consider however:

- The proposal to install carbon capture at the site will reduce emissions from the site overall including long-term NO_x and SO₂, and nutrient nitrogen deposition.
- In unit 94 (Humber Estuary SSSI) the saltmarsh is in favourable condition suggesting it is not being damaged by the high historical background nutrient nitrogen deposition. The unfavourable status for unit 95 is not associated with nutrient nitrogen deposition but instead, according to a site assessment in 2018, it is due to coastal erosion.
- In this 2018 site assessment of units 94 and 95 Natural England comments are as follows '*Condition is assessed with reference to baseline at designation. Targets passed: total extent of saltmarsh/ intertidal reedbed and swamp; invertebrate habitat; absence of undesirable plant species; absence of other negative factors - **including pollution** (excluding inorganic tidal debris), poaching, new drainage, physical damage, increase in bare substrate as a result of anthropogenic activities such as vehicle use or trampling at vulnerable locations; species composition of vegetation communities; zonation of vegetation. This is not a grazed unit so sward height is not applicable. Targets failed: loss of Atlantic salt meadow SAC community due to erosion; Spartina cover >5% (non-mandatory)*'. This suggests the saltmarsh in units 95 and 94 (and SAC/SPA/Ramsar) are not being damaged by the high background nutrient nitrogen deposition which also appears to have been high(er) in 2018.

- North Killingholme Haven Pits SSSI is divided into two areas/units. Unit 1, the closest to the proposed facility is in favourable condition, unit 2 is in unfavourable condition. These condition assessments were undertaken in 2018 and appear to be focused around three targets regarding area of open water, water depth and salinity. No reference is made to nutrient pollution which again appears to have been high in 2018, and likely means that no damage was occurring.
- The reed/ clubrush habitat at North Killingholme Haven Pits SSSI is being regularly managed through periodic cut backs and removal to control its spread into open water habitats, which would further mitigate any changes in vegetation growth due to nutrient nitrogen deposition.

Given the age of the last site survey carried out by Natural England we have consulted with them on the potential impacts highlighted above. If the salt marsh is now in favourable condition, it would provide further evidence that the high background nutrient deposition was not causing damage.

Due to the mitigating factors above, the conservative nature of modelling and the slight reduction in nutrient nitrogen deposition, we conclude that nutrient nitrogen deposition from the proposed permission is not likely to damage any of the designated features associated with the SSSIs subject to this assessment.

We sent the Appendix 4 CROW assessment to Natural England for consultation, and they advised that the operation could go ahead.

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 SSSIs. Finally, 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, Ramsar 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 worst-case future scenario is from the daily mean NOx which is only 24% of the critical level (increase of 20.2% from the baseline assessment) at Mayflower Wood Meadow.

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 2.2.1.

Environment Agency assessment

Although the degree of change is an increase up to 20% for local wildlife sites, the PCs do not exceed the critical level. Therefore, we agree with the applicant's conclusions that the emissions from the installation are unlikely to cause significant pollution.

2.3.1.2 Venting of concentrated carbon dioxide

The release of highly concentrated CO₂ under pressure from the PCC plant 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 CO₂ 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 CO₂ causing harm to health at nearby sensitive receptors.

The applicant provided an assessment in Document no. 215005-00857-00-PM-REP-00001 dated 15th December 2023, which presented a number of venting scenarios:

- start-up;
- shut-down;
- CO₂ off-specification; and
- relief valve discharges.

They used DNV PHAST version 8.7 to predict impacts on nearby receptors and compared these to HSE Workplace Exposure Limit guidance (EH40).

The applicant concluded that concentrations of CO₂ will not result in adverse effects to human health (i.e. CO₂ concentrations of 5,000 ppm (EH40/2005 Workplace exposure limits, January 2020, available at [EH40/2005 Workplace exposure limits \(hse.gov.uk\)](https://www.hse.gov.uk/e402005/) are not exceeded at receptor locations).

The scenario representing the worst-case dispersion impact is associated with controlled venting of the HP system in the event of CO₂ going out of specification.

Environment Agency assessment

We conducted our audit of the applicant's CO₂ venting assessment based on PHAST modelling software version 8.7, including check modelling, sensitivity analysis to our observations and alternative modelling software.

As a result of our checks, we agree with the applicant's approach and conclusions, provided that CO₂ venting is minimised and occurs within the modelled conditions as follows:

- CO₂ venting is infrequent and in accordance with the techniques described in the application, leading to fully expanded CO₂ gas at release with similar characteristics;
- venting at a height of 40 m with a 200 mm diameter; and
- there are no structures that would interfere with the CO₂ plume.

Since submission of the application, we have changed our approach to the assessment of venting of CO₂ from carbon capture activities and no longer request or audit CO₂ venting models.

Consistent with our changed approach, we have included a pre-operational condition in the Permit (PO11). This requires the operator to provide a report that reviews the outcomes of the CO₂ venting emissions to air risk assessment presented in the Application based on the final design. It includes the requirement for a vent management plan and details of the operating techniques to be used to minimise the risks from the venting of CO₂.

2.3.2 Emissions to water

There are no new emission points to water proposed as a result of this variation.

In line with the existing installation, the PCC Plant area will be served by a drainage system that comprises an oily water sewer (OWS) and a surface water sewer (SWS). Water collecting in the PCC Plant SWS will comprise uncontaminated rainwater falling on non-process areas of the PCC Plant and CO₂ compression area (such as paved areas, building roofs, roads and parking areas) and process areas that contain neither equipment requiring frequent or routine maintenance nor equipment where potential leakage may occur.

Potentially contaminated surface waters will drain to the PCC Plant OWS. This will include waters collected in bunded areas, kerbed areas, road-tanker loading/unloading areas and where there is intentional drainage of equipment during normal operation, maintenance or shut down. The waters collected in the PCC Plant OWS will be treated in the existing effluent treatment plant (ETP).

During routine operation, process wastewaters will either be recycled back into the process wherever possible or routed to the OWS (providing the ETP can treat the wastewater and relevant emission limit values can be met). The wastewaters are combined with the refinery's existing wastewater (surface water and process effluent) and discharged via the existing emission point W2a into the South Killingholme Drain (SKD). Between 9,000 and 16,000 cubic metres of treated water from the ETP is discharged per day into the SKD.

According to the application, process wastewaters that cannot be recycled or treated in the ETP will be taken offsite for treatment by a third party licenced waste contractor; in response to the Schedule 5 Notice (dated 16/07/2024), the applicant clarified that:

- PCC plant process equipment containing process solvent will be drained down to the closed Solvent Drain in the event of maintenance activities. Process solvent drained into dedicated sumps in the closed Solvent Drain will be either returned to the process units, returned to solvent storage tanks or sent off-site for disposal.
- Condensed water from the flue gas in the water wash section, and any excess water, will be drained to the solvent loop to prevent solvent build-up in the water wash section and to minimise both solvent and water consumption. This is a closed loop system, and therefore water purged from the water wash system will be used as solvent make-up water under normal operation, either directly into the rich solvent, or by routing it to the solvent storage tank for future solvent dilution. As a closed-loop system, there is no direct way that the water bleed could be drained to the ETP.
- The water removed during the compression process will be recovered into the solvent loop, to minimise wastewater generation where possible, and therefore this represents normal operation. If it is not possible for the water to be recovered to the solvent loop, this water could be used as dilution water for the solvent storage tanks or in the Wet Electrostatic Precipitator (WESP). Use in the WESP is currently being investigated and will be dependent on the potential for there to be amines present within this water, which would preclude its use for this purpose. An alternative use would be as dilution water to the degraded solvent drum, which collects the reclaimers bottoms, as some dilution water is required for this prior to it being sent off-site for disposal.
- There are no identified or anticipated design scenarios for effluents containing amines to be drained to the existing ETP.

An additional effluent stream generated from the Wet Gas Scrubber (WGS) is treated in an additional effluent treatment plant associated with the PCC Plant in the scope of this application, the Purge Treatment Unit (PTU). Refer to section 2.2.2.2 of this decision document for a description and BAT assessment of the PTU process, including consideration of outstanding aspects of the design and pre-operational conditions we have considered necessary to address these outstanding aspects. According to the initial application documents, this stream was not envisaged to be treated in the existing ETP. This position was subsequently amended by the applicant in response to the Schedule 5 notice issued to them on 16/07/2024, and further design work will need to be done to assess the treatability of this effluent in the ETP, in addition to the proposed treatment in the PTU. This section of the decision document assesses the impacts on the recipient water body (the SKD), resulting from the discharge of the PTU effluent, when combined with the effluent currently discharged by the Humber Refinery, through emission point W2a.

Overview of the South Killingholme Drain (SKD)

The SKD is managed by the North-East Lindsey Internal Drainage Board and is part of the Killingholme Marshes drainage scheme. The SKD flows for approximately 3km through an industrialised landscape and joins the River Humber Special Area of Conservation (SAC), Special Protection Area (SPA), Ramsar Wetland of International Importance (Ramsar) and Site of Special Scientific Interest (SSSI) at National Grid Reference TA 18966 17221. The SKD is protected by a tidal flap installed at this location.



SKD in foreground and Phillips 66 ETP ponds behind Route of SKD beside coal stocking areas and container port

Floodwater alleviation ponds, created by the drainage board alongside the SKD, have become a local wildlife site (LWS) - Rosper Road Pools - functionally connected to the Humber Estuary SAC/SPA/Ramsar/SSSI protected sites. Rosper Road LWS is hydrologically connected (via a shallow weir) to the Humber Estuary SAC/SPA/Ramsar/SSSI, as a result of its function as surface water storage during periods of high rainfall when the tidal flaps at the outfall are closed at high water.

The drain is therefore heavily influenced by the Humber Estuary tidal cycle and, during certain tidal periods, the drain becomes tide locked preventing the watercourse from flowing into the estuary. This has a significant effect on the flow regime causing a twice daily rise and fall in the water level in the SKD. At low tide, flows from the SKD run briefly across the intertidal mud area into the estuary. During high rainfall events, usually in conjunction with high tide, when the tidal flaps are closed, the water level in the SKD rises and can overtop the weir into the Rosper Road Pools LWS. At such times, there will be additional dilution from rainwater.

Salinity monitoring, undertaken by the applicant during July to October 2023 (Table 3-4 of report Humber Zero, Sulphate monitoring and analysis – Phillips 66 Refinery Carbon Capture Development, Project number: 60712174, December 2023) indicates the SKD is not affected by saline intrusion.

We have included pre-operational condition PO15 and improvement condition IC37 that require the operator to establish an emission baseline for salinity prior to the commencement of operation of the PCC Plant and to undertake further monitoring and assessment of the salinity of the effluent discharged at emission point W2a once the PCC Plant is fully operational to demonstrate that the salinity of the effluent does not significantly increase the salinity of, or impact the ecological functioning of, the Rosper Road Pools LWS. See the pre-operational/improvement condition section below.

Applicability of the Water Framework Directive to the South Killingholme Drain (SKD)

The SKD is legally defined as a watercourse and a controlled water (see relevant sections of legislation reproduced below). The legal definitions show that drains are defined as watercourses and thereby inland freshwaters if above the freshwater limit, which is the case for the SKD. The '*controlled waters*' definition also states that the watercourse can be dry and includes artificial watercourses. Both are relevant for the SKD as there is low baseline flow, and it is a man-made watercourse.

'Inland Freshwaters' - defined in the *Environmental Permitting (England and Wales) Regulations 2016* by reference to the definition given in section 104 of the *Water Resources Act 1991 (WRA91)*:

'(1)(c) ...the waters of any relevant lake or pond or of so much of any relevant river or watercourse as it above the freshwater limit.'

'Watercourse' - defined in section 221 (WRA91):

*'(1) includes all rivers, streams, ditches, **drains**, cuts, culverts, dykes, sluices, sewers and passages through which water flows.'*

‘Controlled Waters’ - defined in section 104 (WRA91), includes references to inland freshwaters:

‘Controlled Water is defined in the Water Resources Act 1991 Part III – (Relevant points given below)

(1) References in this Part to controlled waters are references to waters of any of the following classes—

(1)(b)(b) in the case of the waters of any relevant river or watercourse, the fresh-water limit of the river or watercourse,

(1)(c) inland freshwaters, that is to say, the waters of any relevant lake or pond or of so much of any relevant river or watercourse as is above the fresh-water limit;

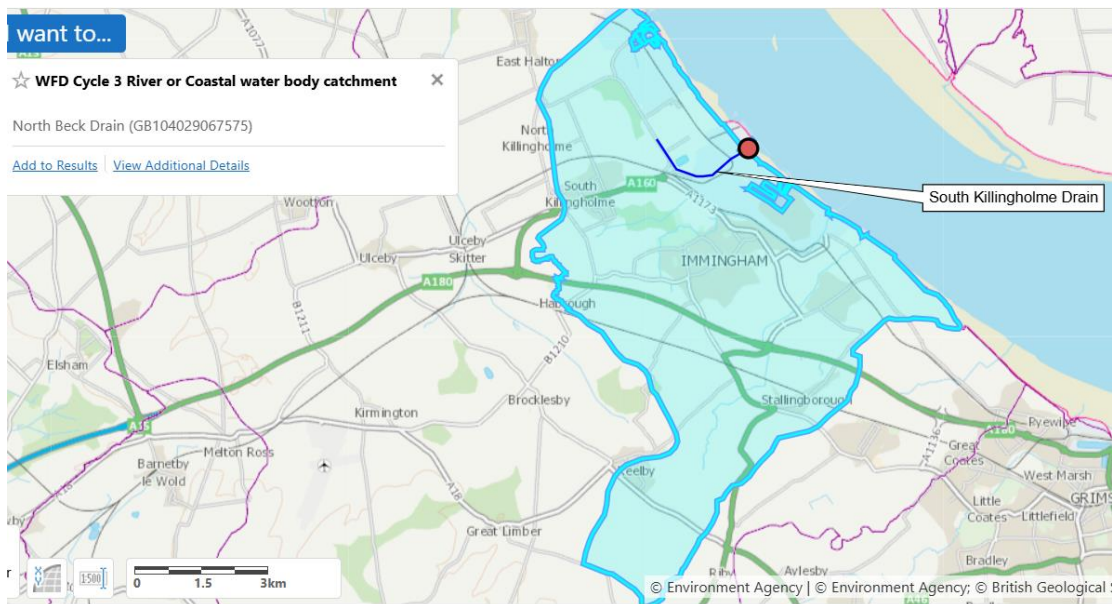
*(2) In this Part any reference to the waters of any lake or pond or of any river or watercourse includes a reference to the bottom, channel or bed of any lake, pond, river or, **as the case may be, watercourse which is for the time being dry.***

(3) In this section—

- *“fresh-water limit”, in relation to any river or watercourse, means the place for the time being shown as the fresh-water limit of that river or watercourse in the latest map deposited for that river or watercourse under section 192 below;*
- *“relevant river or watercourse” means (subject to subsection (4) below) any river or watercourse (including an underground river or watercourse and an **artificial river or watercourse**) which is neither a public sewer nor a sewer or drain which drains into a public sewer.*

According to our guidance ‘Supporting implementation of river basin management plans - position’, the Water Environment (Water Framework Directive) Regulations 2017 (WFD) cover all waters, including inland surface waters, independent of size and characteristics. ‘*Inland water*’ is defined as “*all standing or flowing water on the surface of the land*”. Environment Agency functions apply to all relevant waters, regardless of whether they are designated as water bodies, for the purposes of river basin planning. We may need to use our duties and powers beyond identified water bodies in order to achieve water body objectives.

The Humber Estuary is located within the Humber Lower WFD waterbody (waterbody ID GB530402609201) and is at moderate status. The SKD is within the North Beck Drain (GB104029067575) WFD waterbody catchment.



It follows from the above that WFD applies to the SKD and water quality standards for freshwaters are applicable to this watercourse and have therefore been considered in the impact assessment of emissions to water.

A review of historic permitting of the site indicates that as far back as the original IPPC permit application in 2007, the SKD had been assessed as a freshwater receptor. During the determination of a review of the permit 2018 following the publication of the [Refining of Mineral Oil and Gas BAT Conclusions \(2014/7/738/EU, 28/10/2014\)](#), improvement conditions IC28 and IC29 were added to Table S1.3 of the permit to ensure that, in addition to the review of compliance with the relevant BAT Conclusions, the discharge to water will be reviewed to consider whether water quality objectives under the WFD will be met. At the time of the review, the applicant did not have sufficient information for this assessment to be made, and the improvement conditions were added to address this. This is stated in the decision document that accompanied the issued variation in 2018.

Protected Sites/Interest Features

The SKD is hydrologically connected to the Rosper Road Pools Local Wildlife Site (LWS), which is functionally connected to the Humber Estuary SAC/SPA/Ramsar/SSSI. This means that the Rosper Road Pools LWS is considered to be critical in supporting the ecological or behavioural functions of some of the qualifying features of the statutory protected designation. Protected bird species are features of both sites and Rosper Road Pools are recognised as a roosting and feeding habitat. Natural England have raised particular concern regarding the need to protect the Rosper Road Pools LWS from impact. Any impact on the Rosper Road Pools wildlife site would also impact the Humber Estuary designations.

Surveys of the SKD have also reported records of freshwater protected species being present downstream of the discharge point. Water voles have been

identified, which are protected in the UK under the Wildlife and Countryside Act, 1981. They are listed as endangered on both the Great Britain and the England Red List for mammals.

An amphibious protected species has also been identified. The UK's population of this species is internationally important. They are endangered and numbers are in decline. They are highly sensitive to changes in water quality especially ammonia, a toxic substance that can be dangerous if allowed to accumulate in their water environment due to their porous skin which allows for absorption of harmful chemicals. The species and their eggs, breeding sites and resting places are protected by law. They are protected in the UK under the Wildlife and Countryside Act 1981. They are listed as a European Protected Species under Annex IV of the European Habitats Directive.

Water quality impact assessment of the proposed discharge and ELVs

Most of the effluent generated by the PCC Plant is treated via the existing ETP serving the installation. The additional effluent stream generated from the Wet Gas Scrubber (WGS), is treated in an additional effluent treatment plant associated with the PCC Plant, the Purge Treatment Unit (PTU). In the application, the applicant's proposal was that the treated PTU effluent will bypass the existing ETP and discharge via the existing emission point W2a to the SKD, i.e. it would be discharged after combination with other installation wastewaters. This position was subsequently amended by the applicant in response to the Schedule 5 Notice issued to them on 16/07/2024, and further design work will need to be done to assess the treatability of this effluent in the ETP, in addition to the proposed treatment in the PTU.

The PTU treats wastewater from the WGS (which removes SO₂ from the FCCU flue gas), and includes a clarifier which separates solids (through sedimentation) promoted by the addition of coagulant and flocculant, thus reducing the concentration of suspended solids and metals (e.g. catalyst fines from the FCCU), in the PTU effluent discharge. The solids are collected for off-site disposal by a licensed 3rd party waste contractor.

The PTU oxidises sulphites, present in the WGS effluent, to sulphates thus reducing the chemical oxidation demand of the effluent.

The PTU wastewater is also expected to contain ammonia arising from the selective catalytic reduction of NO_x from the FCC flue gas, prior to the WGS.

As a result of the variation therefore, the effluent discharged at emission point W2a comprises the combined emissions from the refinery's existing ETP (contaminated surface water and refinery wastewaters, treated), uncontaminated surface water drainage and effluent from the PTU.

The PCC Plant will be a first of a kind application to an FCCU and therefore there are no operational plants to provide information to support the application. The

applicant therefore used information provided by the WGS vendor to characterise the PTU effluent (assuming that DeSOx additive is applied to remove 50% of the SOx from the FCC flue gas, prior to treatment in the WGS) and to characterise (by calculating concentrations) the future discharge via emission point W2a when combined and discharged with the existing refinery effluent (presented as Table 5.3 in document Humber Refinery, Environmental Permit Variation Application, Main Supporting Document, Project number: 296344, January 2024), see below.

In the application, the applicant states that the calculated concentrations are conservative because a portion of the salts are expected to be retained within the sludge from the clarifier rather than carrying through to the discharged effluent stream.

In their email of 13/08/2024, the applicant confirmed that the figures provided in Table 5.3 of the application Main Supporting Document (reproduced below) are annual average concentrations.

In the application, the applicant considered that, other than sulphates, the PCC Plant processes would not result in emissions to water that would either add new pollutants or would increase pollutant concentrations over the existing permitted emission limit values at emission point W2a.

Table 5.3: Characterisation of the PTU Wastewater and the Existing Refinery Effluent – with DeSOx Applied

Flows	Unit	PTU Wastewater	Existing Phillips 66 Effluent	Combined Future Effluent to W2	Current W2 ELVs
Mean effluent flowrate	m ³ /s	0.00154	0.10536	0.10690	-
Max effluent flowrate	m ³ /s	0.00295	0.16876	0.17171	0.185*
Average concentrations					
pH	=	8.7	8.8		5 - 9
Na ₂ SO ₄	µg/l	27,344,693	-	-	-
Na ₂ SO ₃	µg/l	409,244	-	-	-
(NH ₄) ₂ SO ₄	µg/l	900,337	-	-	-
Catalyst fines	µg/l	49,109	-	-	-
COD	µg/l	100,000	100,000	100,000	125,000
Phenols	µg/l	0	70	-	500
Suspended Solids	µg/l	50,000	20,000	21,000	25,000
Salts broken out:					
Total Nitrogen*	µg/l	190,869	16,111	18,628	25,000
Ammoniacal Nitrogen	µg/l	190,869	1,267	3,997	Not included
Ammonia	µg/l	232,082	1,540	4,860	Not included
Sulphates	µg/l	19,147,403	261,122	533,092	Not included
Sulphites	µg/l	252,723	-	-	Not included
Catalyst fines broken out:					
Nickel	µg/l	39	8	9	100
Vanadium	µg/l	90	6	7	No limit applied, but monitoring required
Copper	µg/l	1	7	7	100
Iron	µg/l	369	122	130	Not included

* Total Nitrogen (ammoniacal nitrogen = total nitrogen for the new stream as all the nitrogen is present as ammonium)

As the variation involves the release of process effluent containing hazardous pollutants directly to surface water (the SKD), the applicant provided an assessment of water quality impacts as required by our guidance [Surface water pollution risk assessment for your environmental permit - GOV.UK \(www.gov.uk\)](https://www.gov.uk/guidance/surface-water-pollution-risk-assessment-for-your-environmental-permit), using the Environment Agency's H1 Screening Tool. A baseline scenario (impact of releases without the PCC Plant effluent) and a future scenario (with the PCC Plant effluent) were assessed for the following parameters: ammonia, ammoniacal nitrogen, sulphate, nickel, vanadium, copper and iron. These are the parameters which have a potential to be affected by the proposed discharge of the PTU effluent, in the scope of this variation application.

The applicant's assessment indicates that the following parameters do not screen out as insignificant for the future scenario: copper, iron, nickel and sulphate.

We reran the H1 assessment using input values for the relevant parameters stated in Table 5.3 of the application Main Supporting Document (shown above). The

impacts of vanadium and iron emissions screened out of the H1 assessment as insignificant and required no further assessment, according to the screening criteria set out for freshwater in our guidance <https://www.gov.uk/guidance/surface-water-pollution-risk-assessment-for-your-environmental-permit> . According to our guidance, we therefore concluded that emission limit values are not required to be specified in the permit for these substances. We have however included improvement condition IC34 in Table S1.3 of the varied permit to require the operator to undertake monitoring of the effluent for vanadium and iron, once the PCC Plant is fully operational, to validate the assumptions made in the application. See the section on pre-operational/improvement conditions below for further information.

The H1 tool cannot be used for the assessment of sanitary determinands such as COD, suspended solids and ammonia.

Subsequently, the Environment Agency undertook detailed modelling of the emissions to surface water, using the Monte Carlo and MPER modelling software packages for these parameters. These tools utilise a mass balance approach to assess the potential impacts of substances discharged and calculate emission limit values that are protective of the receiving water body, where deemed necessary, taking account of background concentrations, dispersion rates and dilution.

In the model we used the watercourse flowrate collected by the applicant using a handheld meter, as well as a flowrate that we estimated using the Qube modelling package. Qube evaluates a catchment area, geology, topography, land use and climate conditions to estimate watercourse flowrates at an ungauged site by leveraging data from a gauged site with similar parameters. The two flowrates were broadly similar and produced very similar outputs in the model.

Unless the substance concentrations were specifically stated by the applicant to be given in dissolved form, we conservatively assumed that substance concentrations are given as total form.

Background concentrations were input into the model using data provided in the application and also from the Environment Agency's Catchment Planning System.

The modelling focussed solely on substances that are either newly introduced, or have the potential to increase, as a result of the variation, i.e. sulphate, nickel, ammoniacal nitrogen, COD, Suspended Solids and Total Nitrogen. Other substances already discharged by the installation which are not affected by the scope of this variation, are being reviewed as part of compliance assessment of historical improvement conditions IC28 and IC29, and are not addressed here.

Ammonia was not modelled separately; this is taken into account in the modelling of ammoniacal nitrogen.

Substances/parameters that are either not predicted to be present in the PCC Plant effluent, or are not predicted to increase as a result of the variation, were not

modelled, i.e. copper, sulphite, phenol and pH. Where relevant, existing emission limit values for these substances have been retained in Table S3.2 of the varied permit. We have included improvement condition IC34 in Table S1.3 of the varied permit to require the operator to undertake monitoring of the effluent for these substances, once the PCC Plant is fully operational, to validate the assumptions made in the application. See the section on pre-operational/improvement conditions below for further information. Additionally, these parameters will be subject to review under the existing improvement conditions IC28 and IC29.

The modelling indicated that emissions limits were not required to be amended as a result of this variation for the parameters listed below:

- **COD** – the existing 125 mg/l annual average limit is retained.
- **Suspended Solids** – the existing limit of 25 mg/l is retained.
- **Total Nitrogen** – the existing limit of 25 mg/l is retained.

We have included improvement condition IC34 in Table S1.3 of the varied permit to require the operator to undertake monitoring of the effluent for these substances, once the PCC Plant is fully operational, to validate the assumptions made in the application. See the section on pre-operational/improvement conditions below for further information.

For the remaining parameters, the modelling indicated that BAT (where standards exist) would not provide sufficient protection of water quality relative to the EQS. Emissions must not cause breaches of an EQS even if treatment needs to be more onerous than BAT. If meeting an EQS requires a stricter emission limit value than indicated by BAT, we must impose that emission limit value or consider refusing the permit altogether. Emission limit values are therefore required to be added, or amended, as a result of this variation, as described below.

For **Sulphate**, we are adding the following emission limit values:

- 600 mg/l annual average of daily 24-hour composite flow-proportional samples
- 1500 mg/l maximum spot sample

The monitoring data submitted by the operator (Table 3-4 of report Humber Zero, Sulphate monitoring and analysis – Phillips 66 Refinery Carbon Capture Development, Project number: 60712174, December 2023) shows that the upstream sulphate concentration in the SKD (603 mg/l at Site 1 and 700 mg/l at Site 2) is already exceeding the annual average EQS of 400 mg/l.

There is no BAT-AEL for sulphate. We have set limits that take account of operational constraints (such as the efficacy of further SO_x reduction through additional DeSO_x application beyond 50%) whilst still ensuring environmental protection.

On 11 November 2024, we consulted Natural England on the operator's proposed emission limit value of 600 mg/l for sulphate as an annual average. Natural England were supportive of the proposed limit when DeSOX additive is used to mitigate sulphate emissions. Natural England confirmed that, taking account of conservation objectives, the proposal will not adversely affect the integrity of the Humber Estuary SPA/SAC/Ramsar.

The limit requires the operator to control the process to ensure that the average effluent sulphate concentration over a year does not exceed 600 mg/l. The data provided in Table 5.3 indicates that this is achievable. The applicant's predicted concentration of sulphate in the combined future effluent is 533 mg/l.

We have therefore imposed an annual average emission limit value of 600 mg/l, for this parameter, based on the outcomes of the habitats risk assessment and consultation with Natural England.

Our modelling used coefficients of flow variance (CoV) of 0.1 and 1, with a CoV of 1 representing the largest variance in flow. The modelling output indicated a potential range of maximum emission limit values of 1570 mg/l for a CoV of 0.1 and 3657 mg/l for a CoV of 1. We have therefore additionally imposed a maximum emission limit value of 1500 mg/l (on spot samples), for this parameter based on the outcomes of our modelling assessment. The limit is required limit to ensure no deterioration in background quality.

During the determination, the applicant expressed uncertainty over whether compliance with the limit as a spot sample could be guaranteed because the detailed design of the plant has not yet been finalised. However, we consider spot sampling is required to control high sulphate concentrations to ensure no deterioration in background quality. It controls the distribution while using a mean standard, it prevents lots of high results and deteriorating the current 95%ile background quality. It complies with the Environment Agency's 'No deterioration' principles as mean and 95%ile will be maintained.

Data provided by the operator in their H1 assessment (maximum sulphate concentration of 1,440 mg/l) indicates that this limit is achievable and we consider that the further detailed design to be carried out by the applicant would take account of the maximum limit imposed.

Compliance with the limits will protect the SKD from deterioration and will enable the objectives of protecting designated conservation sites, as set out by Natural England, to be achieved. The limits also protect the bird and freshwater species in the watercourse downstream of the discharge.

For more detailed explanation of our consultation with Natural England and our assessment of impacts on habitats refer to the Record of the Screening for Likely Significant Effects (Stage 1 and 2 Habitats Regulations Assessment) and the SSSI Assessment Form (Appendix 4).

We have included improvement condition IC34 in Table S1.3 of the varied permit to require the operator to undertake monitoring of sulphate in the effluent, once the PCC Plant is fully operational, to validate the assumptions made in the application. The limits could then be reviewed if deemed necessary. See the section on pre-operational/improvement conditions below for further information.

For **Nickel**, we are adding an emission limit value for dissolved nickel:

- 0.034 mg/l maximum spot samples

BAT 13 of the Refining of Mineral Oil and Gas BAT Conclusions imposes a BAT-AEL for nickel within the range 0.005-0.100 mg/l. The existing emission limit value included in Table S3.2 of the permit is 0.1 mg/l as an annual average and is retained in the varied permit. However, this concentration is higher than both the annual average EQS (0.004 mg/l bioavailable) and maximum allowable concentration (MAC) EQS (0.034 mg/l) for nickel.

We have set a more stringent limit based on no deterioration on the current situation: we have added a maximum emission limit value of 0.034 mg/l for dissolved nickel to protect the water body in line with the MAC EQS taking into consideration that only dissolved nickel will contribute to bioavailability. The new limit requires the operator to control the process to ensure that the concentration in the effluent does not exceed 0.034 mg/l dissolved nickel. The data provided in Table 5.3 indicates that this is achievable. The applicant's predicted concentration of nickel in the combined future effluent is 0.009 mg/l.

The new limit takes account of operational constraints (such as variability in composition of crude oils processed at the refinery) whilst still ensuring environmental protection. However, we expect this emission limit to be reviewed, and reduced if required, based on the outcomes of the assessment to be carried out as part of an improvement condition. We have therefore included improvement condition IC34 in Table S1.3 of the varied permit to require the operator to undertake monitoring of nickel and other parameters necessary to work out the bioavailable concentration (i.e. dissolved organic carbon, pH and calcium) in the effluent and in the water course, once the PCC Plant is fully operational, to validate the assumptions made in the application. See the section on pre-operational/improvement conditions below for further information.

Ammoniacal Nitrogen, we are adding two emission limit values:

- 5 mg/l 95th percentile of daily spot samples over a quarter
- 20 mg/l maximum daily spot sample

Prior to 2021 the permit included an emission limit value of 10 mg/l (time related 24 hour composite) for ammoniacal nitrogen at emission point W2a. Compliance assessment report UP3230LR/0370210 dated 17/07/2020 records Environment Agency agreement to replace compliance requirements for ammoniacal nitrogen

with total nitrogen. This followed the review of the permit (EPR/UP3230LR/V014) in 2018 after the publication of the Refining of Mineral Oil and Gas BAT Conclusions (2014/7/738/EU, 28/10/2014), which imposed an emission limit value for total nitrogen but not for ammoniacal nitrogen (there is no BAT-AEL for ammoniacal nitrogen). The ammoniacal nitrogen limit was subsequently removed from the permit (EPR/UP3230LR/V016) in 2021.

However, whilst an ELV for total nitrogen is mandated by the implementation of the Refining of Mineral Oil and Gas BAT Conclusions, we consider that ammoniacal nitrogen is more toxic to the freshwater environment compared to total nitrogen. Ammoniacal nitrogen is a specific pollutant as identified in the WFD and is required to be controlled in the permit. On review of the historic permitting at the site we consider that the removal of the ammoniacal nitrogen limit was not justified.

Our guidance [H1 Annex D2, Assessment of sanitary and other pollutants within Surface Water Discharges](#), defines the SKD as a type 7 watercourse because the alkalinity (as mg/l calcium carbonate) is greater than 200mg/l. Our modelling indicates that the upstream 90%ile concentration exceeds 2.5 mg/l. In accordance with Table 7 of the Water Framework Directive (standards and classification) Directions 2015, this is bad status because it exceeds the poor status boundary of 2.5 mg/l.

Our current internal guidance 'Water Quality Planning: no deterioration and the Water Framework Directive' requires us to minimise deterioration of the receiving waterbody by less than 10%. We are currently updating this guidance to minimise deterioration by less than 3%. This 3% level of deterioration is assessed as not being meaningful at a water body scale because it is within the margins of error for sampling and modelling.

We undertook modelling at both 3% and 10% deterioration. Both results point to the same emission limit value, once rounded (4.73 mg/l at 3% and 5.05 mg/l at 10%). We have therefore set a limit of 5 mg/l for daily spot samples over a quarter. In setting this limit we have taken account of operational constraints (such as the limitations of the Cyclical Nitrogen Removal (CNR) technology, which removes nitrogen in the bioreactors of the ETP); the 95%ile limit provides some degree of flexibility to the operator whilst still providing environmental protection.

CNR was implemented at the site in 2019 to meet the new total nitrogen emission limit value. The technology alternates aerobic and anoxic conditions in a continuous-flow aerobic bioreactor by cycling air or oxygen on and off at set intervals to enable complete oxidation of ammonia to nitrate (nitrification) during 'air on' (aerobic conditions) and reduction of nitrate to nitrogen gas (denitrification) during 'air off' (anoxic conditions) in the same tank.

We have also set a maximum limit of 20 mg/l for daily spot samples. The predicted theoretical output of the modelling indicated that a maximum daily limit of 20 mg/l is protective of the water body.

On 31/10/2024, the applicant submitted a Technical Note that provided data in graphical form for ammoniacal nitrogen monitoring of the existing refinery effluent (i.e. without the PCC Plant) during the period 2019 - 2024. Our review of the data indicates that, during this period, the operator would have complied with the proposed limits in 2019, 2023 and 2024. The graphs for 2021 and 2022 indicate that there would have been some exceedances of the proposed limits. The Technical Note explains that one period of non-compliance (approximately one month in 2022) was due to an incident of abnormal operation involving an influx of oil into the bioreactors, causing a loss of biomass activity in the ETP. However, overall the graphs indicate that when the treatment system is working effectively the limits can be achieved. This is supported by the applicant's predicted ammoniacal nitrogen concentration for the combined future effluent to the SKD of 4 mg/l (annual average) as presented in Table 5.3 of the application Main Supporting Document, reproduced above.

We acknowledge that the ETP is not optimised to reduce ammoniacal nitrogen, because there has been no limit on the permit since 2018. The inclusion of limits for ammoniacal nitrogen will require the operator to optimise the ETP to improve the output quality to meet the limits for both ammoniacal nitrogen and total nitrogen. The data provided in Table 5.3 indicates that this is achievable. The predicted concentration of total nitrogen in the combined future effluent is 18.6 mg/l, with an existing permit limit of 25 mg/l. This provides some headroom for optimising the ETP to meet the total nitrogen and ammoniacal nitrogen limits we have set.

We note that the combined future effluent concentration of ammoniacal nitrogen was calculated on the basis of the applicant's original proposal of no treatment of the PTU wastewater (predicted ammoniacal nitrogen concentration 232 mg/l, Table 5.3). The applicant's original proposal was that the PTU wastewater would be discharged at emission point W2a after the existing ETP, i.e. it would be discharged untreated after combination with other installation wastewaters. However, in response to our Schedule 5 notice (dated 16/07/2024), the applicant has subsequently indicated (email, 29/11/2024) their intention to undertake testing of potential treatment options for the PTU wastewater, including via the existing ETP. The testing is required to determine whether the presence of sulphates in the effluent would impact on the biological activity of the ETP. If successful, treatment via the biological stage of the ETP could potentially reduce the concentration of ammoniacal nitrogen. An additional potential benefit of routing the PTU wastewater through the ETP is that undissolved metals could also be further reduced if they are treated via the ETP's induced air flotation and dissolved air filtration stages.

We have included improvement condition IC34 in Table S1.3 of the varied permit to require the operator to undertake monitoring of ammoniacal nitrogen in the effluent, once the PCC Plant is fully operational, to review the assumptions made in the application. The limits could then be reviewed if necessary.

We have also included pre-operational condition PO13 that requires the operator to provide a review of the trials carried out to assess the treatability of the PTU effluent in the existing ETP.

See the section on pre-operational/improvement conditions below for further information.

Pre-operational/improvement conditions (effluent discharge)

We have included improvement condition IC34 to check whether the operator's predicted concentrations for the PTU effluent and combined future effluent stream as presented in Table S5.3 of the application Main Supporting Document (and reproduced above) are representative of the PCC Plant once fully operational. The IC also requires the operator to review whether any additional pollutants might be identified in the effluent.

Monitoring of all relevant substances is required, with a minimum of 12 datasets of sampling for each substance to take into account seasonal variations in effluent quality. We have also required background environmental data to be collected.

The IC requires the operator to provide an updated environmental risk assessment of the impacts on the SKD using the data collected.

We have included pre-operational condition PO13 that requires the operator to provide a review of the trials carried out to assess the treatability of the PTU effluent in the existing ETP. The operator shall confirm whether this is a viable treatment option and if not, the operator shall propose alternative treatment options in order to achieve a reduction in the concentration of ammoniacal nitrogen present in the PTU effluent.

We have included pre-operational condition PO15 that requires the operator, prior to the commencement of operation of the PCC Plant, to undertake monitoring of salinity of the effluent discharged at emission point W2a to establish an emissions baseline. We have also included improvement condition IC37 that requires the operator to subsequently undertake monitoring of the salinity of the effluent discharged at emission point W2a during normal operation of the PCC Plant and to provide an assessment of the results to demonstrate that the salinity of the effluent does not significantly increase the salinity of, or impact the ecological functioning of, the Rosper Road Pools LWS. These conditions were included, as agreed with Natural England, as a condition for their approval of the Habitats Regulations Assessment.

2.3.3 Noise emissions

The application included a noise impact assessment titled 'Noise Impact Assessment, Phillips 66 Ltd, Permit Number: EPR/UP3230LR Humber Refinery, Project number: 60712174 v1' and dated January 2024, based on data from the sources described below and noise modelling using 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 noise impact assessment (NIA) submitted with the application was based on preliminary noise data available at this stage of the design of the proposed carbon capture plant. We have therefore determined that an updated assessment will need to be carried out by the operator to reflect the finalised noise control measures and associated noise levels as a pre-operational condition.

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

- Bureau Veritas (2006) ConocoPhillips Humber Refinery Report on Environmental Noise to Accompany IPPC Application – this report describes a sound survey undertaken while the existing site was operational.
- AECOM (2022) Environmental Statement Chapter 7 Noise & Vibration and Appendix 7A Sound Survey Information – this report presents ambient sound levels and background sound levels with the existing site operational.
- Phillips 66 Community Noise Survey data – this spreadsheet shows measurements made at a location close to receptor NSR1 (Staple Road) on a weekly basis since 1998, including when the site was shut down for an extended period in 2015.
- AECOM (2023) An additional sound survey was undertaken at proxy locations for noise sensitive receptors NSRs 1, 2 and 3 to represent background sound monitoring which excluded any contributions from the operational Humber Refinery site, but also from the adjacent Lindsey Oil Refinery and VPI Immingham CHP site.

The NIA is based on worst-case assumptions, for example: all plant, including cooling fans and the cooling tower, operating at maximum capacity, day and night, during hot weather. Whereas for much of the time, especially during winter months, not all of the cooling equipment will be in use, therefore reducing the overall sound emissions from the proposed plant.

As the detailed design of the proposed carbon capture plant is not yet finalised, for each potential source of noise the assessment provided generic noise attenuation values the applicant 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, barriers, attenuators and sound absorbing surfaces.

The NIA conclusions are based on the successful implementation of noise mitigation measures that achieve the stated attenuation levels.

The applicant also provided an outline Noise Management Plan, version number R05, revision 5, March 2025 which reflects the noise attenuation values that were

modelled for the NIA and which describes how the site will be operated to minimise noise emissions on an ongoing basis.

The NIA focussed on three local noise-sensitive receptors (NSRs): NSR1: Staple Road, NSR2: Clarks Road and NSR3: Church Lane all to the west of the refinery. A fourth NSR was identified at Hazel Dene, Marsh Lane but as the noise climate at this receptor is dominated by noise from the adjacent VPI Immingham CHP this receptor is not considered further in the assessment.

The NIA considered impacts arising from:

- The existing Humber Refinery on its own ('Existing Operations')
- The proposed carbon capture plan on its own ('Proposed PCC Plant')
- The combined impacts of the refinery and the carbon capture plant together ('Existing and Proposed PCC Plant Combined').

Two scenarios were considered in the NIA to establish the specific sound level of existing refinery site operations:

- Scenario 1 – which was based on ambient noise surveys at NSRs undertaken by AECOM in 2022 when the site was operational
- Scenario 2 – which was based on the operator's existing operational noise model for the full Humber Refinery site.

BS 4142 requires that representative background sound levels without contribution from the existing operations at the Humber Refinery are compared against operational sound levels (specific sound levels with additional penalties for acoustic feature corrections, where these may apply at receptor locations). The applicant therefore compared the operational sound levels for the Existing Operations, the Proposed PCC Plant and the Existing and Proposed PCC Plant Combined with data from community noise surveys in 2015 during the last full shut down of the site and from the additional measurements made at proxy locations in 2023.

The applicant also provided an assessment against a second background sound level that included the contribution of noise from existing refinery operations. This scenario is presented by the applicant to be more representative of the receptor's actual experience because of the context of the refinery having been in operation for over 50 years, meaning it is part of the established baseline in the locality. We note that while the fact that the existing site has been operational for several years has been accounted for in our assessment of context, numerical impact assessments against background sound levels which include the operational site are not in line with our noise and vibration guidance ([Noise and vibration management: environmental permits - GOV.UK \(www.gov.uk\)](https://www.gov.uk/guidance/noise-and-vibration-management-environmental-permits)). The conclusions from this scenario were not analysed in detail in our audit.

The applicant's conclusions are based on the results given in Tables 6.1, 6.2 and 6.3 of the NIA.

Existing Operations – the applicant’s BS 4142 assessment indicated for both Scenarios 1 and 2 there is potential for an adverse to significant adverse impact from Existing Operations (NSR 1, 2 and 3).

Proposed PCC Plant - the applicant’s assessment indicated potential for adverse (NSR 2 and 3) to significant adverse impact (NSR1) when the rating level is compared to the background sound level without contribution from the existing refinery. However, the applicant asserts that, when context is taken into account, this can be reduced to a low impact.

Existing and Proposed PCC Plant Combined - for Scenario 1, the applicant’s assessment indicates potential for an up to 2 dB increase in the excess of rating level over background sound level, when compared with the BS 4142 assessment for the Existing Operations (NSRs 1, 2 and 3).

For Scenario 2 the assessment indicates potential for an up to 1 dB increase in the excess of sound level over background sound level, when compared with the BS 4142 assessment for the Existing Operations at NSR 1 and no change at NSRs 2 and 3. The applicant states that these increases are close to the point at which there is an indication of the sound source having a low impact, taking account of both the existing sound climate and acknowledging the PCC Plant predictions are worst case.

The applicant’s overall conclusion therefore is that, considering the BS 4142 assessment outcomes and the context of the existing sound environment, the addition of the proposed PCC plant would have a low impact on nearby NSRs.

We have audited the applicant’s NIA based on the information available at this stage (the outline mitigation measures being accounted for in the predicted impacts) and make the following conclusions:

- We consider that the background sound levels excluding the existing site are conservative and result in a worst-case impact assessment.
- With outline mitigation proposals in place, the applicant’s NIA considers that the impact from the proposed variation will be adverse, which can be reduced to low impact after context is considered. We identified minor discrepancies in the applicant’s modelling files, which result in marginally higher specific sound levels. After assessing context, we consider adverse impacts will occur as a result of the proposed variation. In line with the aims of the Noise Policy Statement for England, Environment Agency guidance and our standard permit condition for noise, adverse impacts are only permissible provided that the site is working to Best Available Techniques (BAT).
- While the NIA suggests impacts from the proposed variation may marginally increase existing significant adverse impacts at certain times, this is based on conservative assumptions regarding the existing operations, background sound data, and the proposed plant operations. We consider that increases

to the overall impact from the site (existing operations with proposed variation added) will be unlikely most of the time.

We have also audited the application Noise Management Plan and, following updates by the applicant (received 24/03/2025), we are satisfied that the attenuation values stated reflect those modelled and assessed in the application NIA and that these levels and the range of attenuation techniques identified are consistent with BAT. We have therefore approved the outline NMP and incorporated it into Table S1.2 (Operating Techniques) of the permit, effectively setting the noise risk envelope for the carbon capture plant. We have also included a pre-operational condition (PO14) in the permit that requires the operator to take certain actions once the detailed engineering design is complete, but before the commencement of carbon capture plant commissioning. The operator is required to submit a revised NIA and NMP that reflects finalised noise control measures, in accordance with BAT, to the Environment Agency for assessment and approval. Commissioning of the carbon capture plant, including any associated activities, shall not commence prior to obtaining written approval from the Environment Agency.

Based upon the information in the application we are satisfied that 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.

3 Decision considerations

3.1.1 Confidential information

A claim for commercial or industrial confidentiality has not been made.

3.1.2 Identifying confidential information

We have not identified information provided as part of the application that we consider to be confidential.

The decision was taken in accordance with our guidance on confidentiality.

3.1.3 Consultation

The consultation requirements were identified in accordance with the Environmental Permitting (England and Wales) Regulations (2016) and our public participation statement.

We consulted the following organisations:

- Local Authority (North Lincolnshire) – Environmental Protection Department
- Local Authority (North Lincolnshire) – Planning Department
- Director of Public Health
- UK Health Security Agency (UKHSA)
- Health and Safety Executive
- North East Lindsey Drainage Board

Only the UKHSA and the North East Lindsey Drainage Board responded to the consultation. The other organisations did not respond.

The comments and our responses are summarised in the [consultation responses](#) section.

3.1.4 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 RGN2 '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. Refer to section 2.1 for the description of the activities.

3.1.5 The site

The applicant has provided a plan which we consider to be satisfactory. This shows the extent of the site of the facility including the new emission points.

There has been no change in the boundary of the facility as a result of this variation.

3.1.6 Nature conservation, landscape, heritage and protected species and habitat designations

We have checked the location of the application to assess if it is within the screening distances we consider relevant for impacts on nature conservation, landscape, heritage and protected species and habitat designations. The application is within our screening distances for these designations.

We have assessed the application and its potential to affect sites of nature conservation, landscape, heritage and protected species and habitat designations identified in the nature conservation screening report as part of the permitting process.

We consider that the application will not affect any site of nature conservation, landscape and heritage, and/or protected species or habitats identified.

We have specified an emission limit for sulphates in the surface water discharge (emission point W2) to protect the water environment, and in particular the Rosper Road Pools LWS, which is functionally connected to the Humber Estuary SAC/SPA/Ramsar/SSSI. Refer to section 2.3.2 for further information.

Refer to section 2.3.1 for the assessment of emissions to air, in relation to protected habitats.

We have consulted Natural England on our Habitats Regulation and SSSI assessments and taken their comments into account in the permitting decision.

3.1.7 Environmental impact assessment

In determining the application we have considered the Environmental Statement.

We have also considered the planning permission and the committee report approving it.

3.1.8 Environmental risk

We have reviewed the applicant's assessment of the environmental risk from the facility.

The applicant's risk assessment is generally satisfactory.

However, the applicant's risk assessment of emissions to water is unsatisfactory and required additional Environment Agency assessment: we reviewed the H1 Tools submitted and consider that the applicant's assessments were completed using incorrect input values. We therefore reran the H1 assessment using input values for all parameters as stated in Table 5.3 of the application Main Supporting Document (shown above). Subsequently, we undertook detailed modelling of the emissions to surface water, using the Monte Carlo and MPER modelling software packages. Refer to section 2.3.2 for further information.

The assessment shows that, applying the conservative criteria in our guidance on environmental risk assessment or similar methodology supplied by the applicant and reviewed by ourselves, all emissions may be screened out as environmentally insignificant, with the exception of:

- SO₂ short-term emissions and nitrosamines for air emissions – Refer to section 2.3.1 for further information and discussion.
- Nickel and sulphates for emissions to water - Refer to section 2.3.2 for further information and discussion.

3.1.9 General operating techniques

We have reviewed the techniques used by the operator and compared these with the relevant guidance notes and we consider them to represent appropriate techniques for the facility. Refer to section 2.2 for additional details.

The operating techniques that the applicant must use are specified in table S1.2 in the environmental permit.

3.1.10 Operating techniques for emissions that do not screen out as insignificant

Emissions of SO₂ and nitrosamines cannot be screened out as insignificant. We have assessed whether the proposed techniques are Best Available Techniques (BAT).

The proposed techniques/ emission levels for emissions that do not screen out as insignificant are in line with the techniques and benchmark levels contained in the technical guidance and our emerging techniques guidance and we consider them to represent appropriate techniques for the facility. The permit conditions enable compliance with relevant BAT reference documents (BREFs) and BAT Conclusions, our emerging techniques guidance and Emission Limit Values (ELVs deliver compliance with BAT- Associated Emission Levels (AELs).

Refer to section 2.2 for additional details of the BAT assessment carried out for the proposed variation.

Refer to section to section 2.3.1 for further information and discussion of emissions to air.

Refer to section 2.3.2 for further information and discussion of emissions to water.

3.1.11 Operating techniques for emissions that screen out as insignificant

Emissions to air of NO₂, NH₃, CO, amines, acetaldehyde, formaldehyde, acetonitrile, ethanol, acetone, antimony and copper; and

Emissions to water of vanadium and iron;

have been screened out as insignificant, and so we agree that the applicant's proposed techniques are Best Available Techniques (BAT) for the installation.

We consider that the emission limits included in the installation permit reflect the BAT for the sector.

3.1.12 National Air Pollution Control Programme

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.

3.1.13 Noise and vibration management

We have reviewed the noise and vibration management plan in accordance with our guidance on noise assessment and control.

We consider that the noise and vibration management plan is satisfactory and we approve this plan.

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'.

We have approved the noise and vibration management plan as we consider it to be appropriate measures based on information available to us at the current time. The applicant should not take our approval of this plan to mean that the measures in the plan are considered to cover every circumstance throughout the life of the permit.

The plan has been incorporated into the operating techniques in table S1.2 of the varied permit.

We have also included pre-operational condition (PO14) that requires the operator to take certain actions once the detailed engineering design is complete, but before the commencement of carbon capture plant commissioning. The operator is required to submit a revised NIA and NMP that reflects finalised noise control measures, in accordance with BAT, to the Environment Agency for assessment and approval.

Refer to section 2.3.3 for additional details.

3.1.14 Environment Agency initiated variation

We have varied the permit as stated in the variation notice.

We have updated Table S1.1 of the permit to include a list of existing Directly Associated Activities (DAAs), beyond the scope of the variation applied for by the applicant. These DAAs were already undertaken at the installation and regulated by us, but were not clearly stated in the permit prior to this variation.

3.1.15 Raw materials

We have specified limits and controls on the use of raw materials in Table S2.1 of the permit. We have specified the following for the solvent Shell CANSOLV DC-103: formulation consistent with emission profile assessed in the variation application documents. We expect that, should the solvent or its composition change, the operator will need to vary the permit to assess any changes to the risk profile of the carbon capture operations.

3.1.16 Pre-operational conditions

Based on the information in the application, we consider that we need to include pre-operational conditions:

- **PO8** - Requirement to submit a **Commissioning Plan**. Refer to sections 2.2.1 and 2.3.1 for the reasons of this requirement.
- **PO9** - Requirement to submit a report confirming the successful **completion of commissioning prior to start-up and decommissioning of emission point A6b**. Refer to sections 2.1 for the reasons of this requirement.
- **PO10** - Requirement to confirming the **extension of the installation's EMS** to include the new activities. Refer to section 2.2.1 for the reasons of this requirement.

- **PO11** - Requirement to submit an updated CO2 venting assessment and **Venting Management Plan**. Refer to sections 2.2.1 and 2.3.1.2 for the reasons of this requirement.
- **PO12** – Requirement to submit an updated report on the **detailed design and construction specification of the primary, secondary and tertiary containment** infrastructure. Refer to section 2.2.1 for the reasons of this requirement.
- **PO13** – Requirement to submit a report addressing the proposed **final design of Purge Treatment Unit (PTU) and updated water quality risk assessment**. Refer to sections 2.2.2.2 and 2.3.2 for the reasons of this requirement.
- **PO14** – Requirement to submit an updated **Noise Impact Assessment and Noise Management Plan**. Refer to section 3.1.13 for the reasons of this requirement.
- **PO15** - Requirement to submit a **salinity monitoring baseline** report. Refer to section 2.3.2 for the reasons of this requirement.
- **PO16** – Requirement to confirm the emissions **monitoring locations and configuration for the CEMS** installed to emission point A6c and A6d. Refer to section 2.2.2.1 for the reasons of this requirement.
- **PO17** - Requirement to submit a report to confirm the techniques implemented in the final design to **reduce emissions of VOCs from the storage** of the carbon capture solvent. Refer to section 2.2.2.1 for the reasons of this requirement.
- **PO18** - Requirement to submit details of **the process monitoring methods for absorber amine solvent quality**. Refer to section 2.2.1 for the reasons of this requirement.
- **PO19** - Requirement to submit an **OTNOC management plan** for the PCC plant. Refer to sections 2.2.1 for the reasons of this requirement.

3.1.17 Improvement programme

Based on the information on the application, we consider that we need to include an improvement programme.

We have included the following improvement conditions:

- **IC31** - Requirement to submit a report confirming that, upon completion of the commissioning and performance testing, the **environmental**

performance of the PCC plant and associated activities meet all the specifications stated in the permit application V021 and that the activities are capable to operate in compliance with the permit and within the risk envelope assessed in the application and the relevant pre-operational conditions, as approved by the Environment Agency. We consider this is necessary due the complexity of the proposed activities, the preliminary status of the design that has informed this variation application and the first of a kind nature of the activities being permitted.

- **IC32** - Requirement to submit a report confirming the attainment of the design **carbon capture performance** over the first year of operation. Refer to sections 2.2.1 for the reasons of this requirement.
- **IC33** - Requirement to submit a report on the **degradation of PCC absorber solvent quality** over the first year of operation. Refer to section 2.2.1 for the reasons of this requirement.
- **IC34** - Requirement to submit a **review of the risk assessment of PTU effluent and combined discharge**. Refer to section 2.3.2 for the reasons of this requirement.
- **IC35** - Requirement to submit a report to **confirm the compliance of the new monitoring points for emissions to air with BS EN 15259**. Refer to sections 2.2.1 for the reasons of this requirement.
- **IC36** - Requirement to submit a **review of the Refinery Integrated Management Emissions Technique** (refinery bubbles) for oxides of nitrogen (expressed as NO₂) and sulphur dioxide (SO₂) and to propose reduced monthly emission limits for the calculation of the NO_x and SO₂ refinery bubbles to be applied to emission point A6d. Refer to section 2.2.2.32.2.1 for the reasons of this requirement.
- **IC37** - Requirement to carry out monitoring and an **appraisal to demonstrate that the salinity** of the effluent discharged through emission point W2 does not significantly increase the salinity of, or impact the ecological functioning of the Rosper Road Pools Local Wildlife. Refer to section 2.3.2 for the reasons of this requirement.
- **IC38** - Requirement to submit a **review of the risk assessment for the emissions to air from the PCC plant**. Refer to section 2.3.1 for additional details.
- **IC39** - Requirement to **optimise the dosing of DeSO_x additive** to attain a reduction in the concentrations of sulphates in the PTU waste water effluent. Refer to sections 2.2.1 for the reasons of this requirement.

We are satisfied that the specified improvement programme can be achieved by the operator and that it will address and mitigate the residual risks associated with uncertainties of the design.

3.1.18 Emission limits

Emission Limit Values (ELVs) and equivalent parameters or technical measures based on Best Available Techniques (BAT) have been added/amended for the following substances:

Emissions to air

Refer to sections 2.2.2.3, 2.2.2.4 and 2.3.1 for additional details and explanations of the rationale for setting these ELVs.

- **Emission Point A6c (PCC Absorber Stack):**
NO_x, CO, SO₂, Particulates, Ammonia, Total Amines, Total nitrosamines and nitramines, Total Amides and Formamides, Formaldehyde, Acetaldehyde.
- **Emission Point A6d (WGS Stack and flue line):**
NO_x, CO, SO₂, Particulates and Ammonia.

Emissions to surface water (emission point W2a/b to South Killingholme Drain)

Emissions limits have been added or amended as a result of this variation for the following parameters:

Dissolved Nickel, Sulphates and Ammoniacal Nitrogen

It is considered that the numeric limits specified in the permit will prevent significant deterioration of receiving waters. Refer to section 2.3.2 for additional information.

These emission limits will apply from the start-up of the activities in the scope of this variation application.

3.1.19 Monitoring

We have decided that monitoring should be added for the following parameters, using the methods detailed and to the frequencies specified. Refer to sections 2.2 and 2.3 for further details.

Emissions to air

- **Emission Point A6c (PCC Absorber Stack):**
 1. NO_x, CO, SO₂, Particulates, Ammonia, total and speciated amines, total and speciated nitrosamines and nitramines, total and speciated amides and

formamides, Formaldehyde, Acetaldehyde, acetone, ethanol, acetonitrile, acetic acid, carbon dioxide, oxygen, flow, water vapour, temperature and pressure.

Monitoring requirements for metals (Nickel, Antimony and Vanadium) are also included to ensure continued compliance with the monitoring requirements of the REF BAT conclusion 4 for the FCCU plant.

- **Emission Point A6d (WGS Stack and flue line):**

NO_x, CO, SO₂, Particulates and Ammonia, oxygen, flow, water vapour, temperature and pressure.

Monitoring requirements for metals (Nickel, Antimony and Vanadium) are also included to ensure continued compliance with the monitoring requirements of the REF BAT conclusion 4 for the FCCU plant.

We made these decisions in accordance with the outcomes of the environmental risk assessment, the 'Refining of Mineral Oil and Gas BAT Conclusions' and our guidance: [Post-combustion carbon dioxide capture: emerging techniques - GOV.UK \(www.gov.uk\)](https://www.gov.uk/guidance/post-combustion-carbon-dioxide-capture-emerging-techniques); [Monitoring stack emissions: carbon capture plants with solvent-based abatement - GOV.UK](https://www.gov.uk/guidance/monitoring-stack-emissions-carbon-capture-plants-with-solvent-based-abatement); and [Monitoring stack emissions: techniques and standards for periodic monitoring - GOV.UK](https://www.gov.uk/guidance/monitoring-stack-emissions-techniques-and-standards-for-periodic-monitoring).

Emissions to surface water (emission point W2a/b to South Killingholme Drain)

- Dissolved Nickel, Sulphates and Ammoniacal Nitrogen.

We made these decisions in accordance with the outcomes of the environmental risk assessment and our guidance [Monitoring discharges to water: guidance on selecting a monitoring approach - GOV.UK](https://www.gov.uk/guidance/monitoring-discharges-to-water-guidance-on-selecting-a-monitoring-approach).

Process monitoring

- Absorber amine solvent quality: solvent opacity and colour, concentration of active amines, carbon dioxide loading (rich amine), foaming tendency, amine and organic non-ionic degradation products prior to reclaiming and after reclaiming, heat stable salts, organic acids, metals including soluble iron concentration, soluble iron concentration in the rich amine,
- Other operating parameters: carbon capture efficiency (%) during normal operation, exported CO₂ mass flow (tonnes/hour), composition of exported CO₂, information on venting of CO₂ from emission point A39.

We made these decisions in accordance with our guidance: [Post-combustion carbon dioxide capture: emerging techniques - GOV.UK \(www.gov.uk\)](https://www.gov.uk/guidance/post-combustion-carbon-dioxide-capture-emerging-techniques).

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.

3.1.20 Reporting

We have added reporting in the permit for all the parameters specified to be monitored.

3.1.21 Management system

We are not aware of any reason to consider that the operator will not have the management system to enable it 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.

3.1.22 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 variation.

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.”

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.

4 Consultation Responses

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.

4.1.1 Responses from organisations listed in the consultation section

Response received from the UK Health Security Agency (UKHSA) – dated 10/05/2024

Brief summary of issues raised:

The UKHSA made representations on the following areas of the application (summarised in italics) and requested the Environment Agency to take them into account in the permit determination:

- *Clarification on which chemicals are emitted from the carbon capture stack, and associated justification for the assessment of atmospheric emissions, including composition of oxides of nitrogen. Assessment or whether the predicted air concentrations are sufficiently below the short-term and long-term air quality standards for carbon monoxide, particulates, sulphur dioxide, ammonia, formaldehyde and acetaldehyde. Consideration of cumulative impacts.*

Summary of actions taken by the Environment Agency:

In the Schedule 5 Notice served to the applicant on 16/07/2024, we requested additional information from the applicant on the risk assessment of certain pollutants that were identified in the application as potential solvent degradation products but had not been assessed: these included amides and formamides, acetonitrile, ethanol and acetone.

We also requested a cumulative assessment for emissions of nitrosamines, taking into account the nearby proposed VPI Immingham carbon capture project and other carbon capture projects planned in the area. In a second Schedule 5 Notice issued on 26/02/2025 we requested a revised assessment of the impacts from emissions of nitrosamines and emissions of amides.

We requested additional information on emissions to air during OTNOC scenarios, in particular during breakdown or malfunctioning of the proposed flue gas abatement equipment.

We have specified an improvement condition (IC31) requiring evidence that the Selective Catalytic Reduction system is optimised during the commissioning and

early operations to prevent or minimise emissions of ammonia due to ammonia slip and nitrous oxide due to excessive reduction of nitrogen-containing species.

Refer to section 2.3.1 for details of the air emissions risk assessment and our conclusions. Refer to section 2.2 for our review of the proposed operating techniques for prevention and abatement of emissions to air against the relevant BAT conclusions and other relevant guidance.

- *Toxicology comments: The Environment Agency may consider asking for revised justification for the use of certain EALs to determine potential health risk from the amines contained within CANSOLV DC-103. Insufficient justification provided for the use of the EAL for MEA to assess the potential health risk of the sum of Amine 1 and Amine 3 exposure. Insufficient justification was provided for the use of the applicant derived EALs to assess the potential health risk of Amine 2.*

Summary of actions taken by the Environment Agency:

Refer to section 2.3.1 for details. In summary:

For Amine 2 (Piperazine): Working with the UKHSA, we have derived an EAL for piperazine of 0.015 mg/m³ (15 µg/m³) averaged over 24 hours to protect public health. 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/m³ is not that dissimilar from the one proposed by the applicant of 17 µg/m³, although we consider that the methodology and the explanation given by the applicant were not as robust as the evidence gathered and methodology used in our dossier.

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

For Amine 1 (1-Piperazineethanol) and 3 (1,4-Piperazinediethanol): We requested additional information and justification for the proposed use of the EAL for MEA from the applicant in the Schedule 5 Notice served on 16/07/2024. We informed our requests for additional information with the more detailed comments and advice received from the UKHSA to the consultation for the VPI Immingham CHP carbon capture project, that consists of the same solvent and proposes the same approach to risk assessment for amines emissions. A response was received from the applicant on 02/10/2024. We re-consulted the UKHSA on the response received from the applicant, refer to the next section on the consultation response from the UKHSA date 12/02/2025.

- *The explanation for approach to the assessment of nitrosamines and nitramines was confusing. The summary of the toxicity data relating to*

these substances was unclear, confusing, and often not relevant. The Ames test is not suitable to estimate the carcinogenic potency of various chemicals. However, the UKHSA noted that, due to the lack of sufficient data for most nitrosamines and nitramines, comparison with the EAL for the potent carcinogen NDMA for total nitrosamines and nitramines as a proxy is a pragmatic approach and this indicated a likely minimal risk to health.

Summary of actions taken by the Environment Agency:

We have carried out our determination in line with the advice from the UKHSA: we have compared emissions of nitrosamines and nitramines against the EAL for NDMA. Refer to section 2.3.1 for details of air emissions risk assessment.

- *The reduction and scrubbing of emissions of feed gas to the carbon capture process should work to reduce the concentrations of other pollutants, or as a very conservative estimate, will not lead to an increase (as shown by the modelled data).*

Summary of actions taken by the Environment Agency:

No action taken / required as the comment was positive. Refer to section 2.2 for the assessment of the proposed operating techniques against BAT and emerging technologies guidance.

- *Consideration of nearby groundwater extractions which may be impacted by the effluent discharge into South Killingholme Drain, particularly from the sulphate emissions which have emission limits still to be decided. Recommended to consider potential impacts on abstraction points and private water supplies.*

Summary of actions taken by the Environment Agency:

Burnham Chalk Formation is the Principal Aquifer that underlies the site and is the source for the abstractions in the area. This chalk is overlain by around 19 metres of clayey drift deposits which will provide significant protection. Therefore, we consider there is no likely pollutant linkage to the groundwater in the chalk from site activities or surface waters. We have searched our data set and there are no private domestic water supply boreholes within a 500 metres radius of the site. We consider the proposed surface water discharge poses a low risk to public health due to potential for groundwater contamination.

- *Consideration of potential odour impacts associated with the amines contained in the CANSOLV DC-103 solvent and their degradation products, and ammonia during normal and abnormal operations, including loss of containment.*

Summary of actions taken by the Environment Agency:

According to the application, the CANSOLV DC-103 solvent has very low volatility and therefore is not considered to represent a particular odour risk. Section 2.2.2.1 provides details of BAT assessment for the potential emissions associated with the storage of solvent. The applicant proposed that further consideration of specifying a white painted or milled finish storage to reduce losses will be given during the detailed design stage and we have set this requirement in a pre-operational condition (PO17).

In the Schedule 5 Notice served to the applicant we requested additional information on the operating techniques proposed to prevent and minimise fugitive emissions of ammonia with a potential to cause odour impacts to nearby receptors. In their response, the applicant confirmed that the ammonia tank will consist of an unvented, nitrogen blanketed pressurised storage, with balanced tanker loading. Therefore, we consider there is minimal potential to cause odour impacts at nearby receptors from fugitive emissions of ammonia.

The applicant confirmed that the PCC Plant will be part of the Installation's maintenance and operations programme and LDAR programme to prevent, minimise, detect and repair as required fugitive emissions associated with leaks.

The permit includes condition 3.4.2 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 have set a pre-operational condition (PO10) requiring the operator to confirm the extension of the existing installation Environmental Management System, including accident response plans, maintenance and LDAR programmes, to the PCC plant and associated equipment, prior to the beginning of its operations; and a pre-operational condition requiring the operator to develop a specific OTNOC Management Plan (PO19).

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

- *Consideration of fire and explosion prevention surrounding the storage of ammonia.*

Summary of actions taken by the Environment Agency:

We requested additional information from the applicant in the Schedule 5 Notice served on 16/07/2024. The applicant confirmed that the ammonia storage will be blanketed with inert gas (nitrogen) – refer to section 2.2.2.1. It should also be noted that the installation is regulated as an upper tier COMAH site under the Control of Major Accident Hazards (COMAH) Regulations and that the applicant confirmed that the COMAH Safety Report will be updated to include considerations relating to the installation of the PCC Plant. Refer to item 3.5.1 of

section 2.2.1. We expect the updated Safety Report to address in detail process safety hazards (such as fires and explosions) and the associated risks.

Response received from the UK Health Security Agency (UKHSA) – dated 12/02/2025

Brief summary of issues raised:

We re-consulted the UKHSA on the toxicology information presented by the applicant in response to the Schedule 5 Notice questions (received 02/10/2024) that we had raised taking into account the comments received by the UKHSA in the first consultation round. The UKHSA responses and our actions are summarised in the following:

- *The information provided is not sufficient to illustrate why MEA would be an appropriate read across for Amines 1, 2 and 3. As there is closer structural similarity of Amine 1 and Amine 3 to Amine 2 (piperazine), UKHSA considers that piperazine is a more appropriate substance to read across from than MEA for the other two amines. Information provided by the Environment Agency (EA) reports that the total process contribution concentration of all 3 amines (Amine 1 + Amine 2 + Amine 3) is 0.056 $\mu\text{g}/\text{m}^3$. This is substantially below the proposed EAL for piperazine of 15 $\mu\text{g}/\text{m}^3$, by a margin of over 250. Therefore, acknowledging the uncertainty, this is unlikely to present a risk to health.*

Summary of actions taken by the Environment Agency:

In line with the comment received from the UKHSA we assessed emissions and process contributions of all the amines emitted by the process against the Environmental Assessment Level for piperazine. Refer to section 2.3.1 for details of the air emissions risk assessment and our conclusions.

- *With regards to the amides, the EAL for acrylamide was used. It was unclear from the application as to whether there would be an emission of amide and formamide degradation products, and what those concentrations would be at downstream receptors. The information provided did not provide sufficient justification for using the acrylamide EAL, and a more reasoned argument drawing on lines of evidence would be helpful, as would providing references for any values used as part of this argument. However, the UKHSA expanded commenting that acrylamide is recognised as mutagenic and carcinogenic. Such mutagenic substances that can cause cancer via a genotoxic mode of action are assumed to have no threshold level of exposure below which adverse effects cannot occur. The lower the exposure the lower the risk. Therefore, exposure to mutagenic substances should be as low as reasonably practicable (ALARP). This implies that any EAL for a mutagenic and carcinogenic substance such as acrylamide is set at a level that presents*

a minimal risk to health and at a relatively low exposure. This is a line of evidence that the applicant may wish to consider. It would be helpful if the applicant could demonstrate that the predicted concentration for the sum of all amides and formamides (total amides) is below the EAL for acrylamide. However, the UKHSA noted that the acrylamide EAL used by the applicant was still not the most up to date one.

Summary of actions taken by the Environment Agency:

The applicant presented the following justification: 'since 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 is very conservative'. This is similar to the comment made by the UKHSA: we consider that since the '*EAL for a mutagenic and carcinogenic substance such as acrylamide is set at a level that presents a minimal risk to health and at a relatively low exposure*' this is likely to represent a conservative EAL for assessment of amides that are not mutagenic and carcinogenic.

In the Schedule 5 Notice issued to the applicant on 26/02/2025 and responded on 31/03/2025, we requested the applicant to reassess the process contributions of total amides (sum of amides and formamides) against the correct published EAL for acrylamide (i.e. $0.05 \mu\text{g}/\text{m}^3$). We compared the predicted concentrations of the sum of all amides and formamides against the EAL for acrylamide, as advised by the UKHSA. Refer to section 2.3.1 for details of the air emissions risk assessment and our conclusions.

- *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. The UKHSA recommended to consider cumulative impacts for total nitrosamines and nitramines in the area.*

Summary of actions taken by the Environment Agency:

In the Schedule 5 Notice dated 26/02/2025, we requested from the applicant an updated assessment of the impacts of nitrosamines and nitramines (from the proposed carbon capture plant alone and in combination with other carbon capture plants proposed and in development in the area). The response was received on 31/03/2025. Refer to section 2.3.1 for details of the air emissions risk assessment and our conclusions.

- *If the predicted concentrations for acetonitrile and acetone are below the respective EALs for these compounds, then it does not indicate a risk to health. If the predicted maximum air concentration of ethanol (i.e., reported to be $2 \mu\text{g}/\text{m}^3$) is below the REACH registration dossier for ethanol DNELs for inhalation. Then, this is unlikely to present a risk to health.*

Summary of actions taken by the Environment Agency:

No action taken / required. Refer to section 2.3.1 for details of the air emissions risk assessment and our conclusions.

Response received from the North East Lindsey Drainage Board

Brief summary of issues raised:

The consultee confirmed they had no comments on the variation.

No further action was taken.

4.1.2 Representations from individual members of the public

Brief summary of issues raised:

- *Concern about failure to follow our Guidance on Emerging Techniques for Post-combustion Carbon Dioxide Capture regarding the selection of the carbon capture process solvent.*

Summary of actions taken by the Environment Agency:

As part of our determination, we requested additional information from the applicant on the solvent selection process. Our questions were responded by the applicant on 02/10/2024.

Our review of the application and additional information against the requirements of Guidance on Emerging Techniques for Post-combustion carbon dioxide capture, relevant to solvent selection, is set out in section 2.2.1 (item 3.2 of Table 1 – BAT / GET assessment).

On review of the application and additional information submitted by the applicant in response to our requests, we are satisfied that the proposal meets the requirements of our guidance on emerging techniques in relation to the selection of the carbon capture solvent. Refer to section 2.2.1 for additional details.

- *Concern that there should be no contractual barrier to using alternative solvents.*

Summary of actions taken by the Environment Agency:

No action taken: the contractual arrangement between the applicant and technology/solvent providers is not a matter regulated by the environmental

permit. We consider we have no discretion on this matter within the remit of the Environmental Permitting Regulations. We have decided we need to restrict the operations to the solvent proposed in the application and we have included this as a specification in the permit. This is because our assessment of the application is based on the proposed solvent and any changes to the solvent might entail a change to the environmental risk of the permitted activities. Therefore, any changes to the solvent will require the operator to submit an application to vary the Permit, which would be assessed on its own merits.

- *Concern about absorber emissions abatement, in particular about the fact that only water wash is proposed to be fitted; and that this may not achieve satisfactory abatement of amine and ammonia emissions. An additional acid wash would offer improved performance in both respects. Incorrect statement that a simple absorber water wash would stop emissions of ammonia and other volatile species.*

Summary of actions taken by the Environment Agency:

As part of our determination, we requested additional information from the applicant on the configuration and effectiveness of the proposed absorber abatement. We requested the applicant to explain what set of data supported the conclusion that acid wash was not required and whether this data supported the conclusion that simple water wash, in absence of acid wash, will be sufficient to abate ammonia and solvent degradation products that might accumulate in the system and be emitted from the top of the absorber.

Our questions were responded by the applicant on 02/10/2024.

Our review of the application against the requirements Guidance on Emerging Techniques for Post-combustion carbon dioxide capture, in relation to the abatement of the absorber emissions, is set out in section 2.2.1 (item 3.3.3 of Table 1 – BAT / GET assessment).

On review of the application and additional information submitted by the applicant in response to our requests, we are satisfied that the proposed water wash, including provision for its expansion, meets the requirements of our guidance for water wash.

We note that the proposed emission levels for amines, solvent degradation products and ammonia 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. We therefore consider we are not able to impose the implementation of the acid wash technique.

On review of the application and additional information submitted by the applicant in response to our requests, 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. Refer to section 2.2.1 (item 3.3.3.2 of Table 1 – BAT / GET assessment) for further details.

- *Comment that the technology being proposed, amine post-combustion capture, is well-established, having been initially developed nearly 100 years ago; that however while amine capture technology is a reasonable choice for retrofit deployment on a refinery flue gas in the immediate future 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 even give satisfactory long term performance.*

Summary of actions taken by the Environment Agency:

This comment relates to the solvent selection process. As part of our determination, we requested additional information from the applicant on the solvent selection process. Our questions were responded by the applicant on 02/10/2024.

Our review of the application against the requirements Guidance on Emerging Techniques for Post-combustion carbon dioxide capture, relevant to solvent selection, is set out in section 2.2.1 (item 3.2 of Table 1 – BAT / GET assessment).

On review of the application and additional information submitted by the applicant in response to our requests, we are satisfied that the proposal meets the requirements of our guidance on emerging techniques in relation to the selection of the carbon capture solvent. Refer to section 2.2.1 for additional details.

- *Concerns on limited information provided from pilot tests and other operational experiences of use of the Shell CANSOLV DC-103 solvent, in particular in relation to its reclamation; concern on whether or not the 'DC-103' solvent that will be used in the plants referred to in the application is the same as the one being used in other Shell CANSOLV projects that are being cited as supporting the likelihood of satisfactory operation.*

Summary of actions taken by the Environment Agency:

As part of our determination, we requested additional information from the applicant on pilot tests carried out by Shell, the solvent provider, including request for confirmation that reclaiming process is able to maintain a stable working solvent composition over long term operations; and whether the solvent used in the trials consisted of the same composition of the one proposed for the carbon capture plant at the Humber Refinery. Our questions were responded by the applicant on 02/10/2024.

The applicant responded that the reclaiming method proposed to be used at Phillips 66 (separation of amine and degradation products by vacuum distillation) is the same as used in the Boundary Dam and Brother CISA commercial units. Lessons learnt from this project have been taken into account in the design for new projects using Shell licensed technology by including sufficient spare capacity in the design of the reclaimer. Overdesign of the thermal reclaimer is proposed to deal with potentially higher NO₂ content than that used for the design basis and to prevent and mitigate uncertainties of the design in relation to efficiency of the absorber emissions abatement system, given that the application acknowledges this is a first of a kind project.

The applicant provided additional information on several CANSOLV pilot trials, including a more recent trial carried out on catalytic cracker flue gas between February and August 2023 at the Technology Centre in Mongstad, in Norway. This campaign was aimed at testing operation with several CANSOLV DC-103 formulations (including the formulation to be used in the Phillips 66 PCC) with the two flue gas sources available at the TCM test centre (catalytic cracking off-gas and the CHP from the co-located refinery).

According to the additional information provided, the measurements performed during trials allowed Shell to validate the structure of the emission prediction models, i.e. the contributions taken into account (components volatility, liquid entrainment, aerosols induced emissions) and the applicant remarked that tests performed with other CANSOLV solvent formulations were still relevant to inform the predictive model.

This is addressed in more detail in section 2.2.1 (item 3.2.2 of Table 1 – BAT / GET assessment).

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.

We have specified in the permit that the Shell CANSOLV DC-103 formulation shall be consistent with the one determining the emission profile assessed in this variation application (emissions of amines and their degradation products reported in Annex A of application document 'Environmental Permit Variation Application Appendix D - Air Impact Assessment', received on 30/01/2024). This is to prevent changes to the environmental risk associated with potential future changes of the formulation of the solvent. Should this happen, the operator will need to apply for a variation of the permit.

- *Concerns on nitrosamine accumulation or methods to limit or remove nitrosamines*

Summary of actions taken by the Environment Agency:

As part of our determination, we requested additional information from the applicant on the potential accumulation of solvent degradation products. Our questions were responded by the applicant on 02/10/2024.

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). This is addressed in section 2.2.1 (item 3.3.2.2 of Table 1 – BAT / GET assessment), that we refer for further details.

We are satisfied that the proposal is compliant with our guidance on emerging techniques in relation to consideration given to the potential degradation of the solvent, however we have set an improvement condition (IC33) 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.