Permitting decisions

Variation

We have decided to grant the variation for Winnington Sodium Carbonate Manufacturing Site operated by Winnington CHP Limited.

The variation number is EPR/EP3337NY/V005.

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.

Purpose of this document

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

- highlights key issues in the determination
- summarises the decision making process in the decision checklist to show how all relevant factors have been taken into account

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. The introductory note summarises what the variation covers.

Key issues of the decision

1. Biodiversity, heritage, landscape and nature conservation

Emissions to air

The proposed Carbon Capture and Usage (CCU) Plant may have an adverse effect alone from ammonia and nutrient nitrogen deposition at the qualifying feature of Witton Lime Beds (SSSI). However, this is mainly due to the current background levels of both ammonia and nutrient nitrogen deposition already significantly exceeding the relevant Critical Level (Cle)/Critical Load (Clo). The Process Contributions (PCs) from the CCU Plant (10% of the Cle and 3.6% of the Clo respectively) are small in comparison to the background levels. The main contributions to the background concentrations are from livestock.

The in-combination assessment shows that there are no other sites that could act in-combination with the proposed Carbon Capture Plant at all of the identified nature conservation sites or protected species or habitats.

In addition to the PC from the carbon capture plant being relatively small, the emissions to air risk assessment has currently been carried out using highly conservative emissions data. A pre-operational condition (PO 01) and improvement conditions (IC13 – IC16) are included in the permit which require the operator to validate the emissions to air, repeat the impact assessment submitted with the application with actual monitoring data, and provide a long term monitoring plan for the Carbon Capture Plant. An assessment shall be made of the impact of each parameter against the relevant environmental standard. In the event that the assessment shows that an environmental standard can be exceeded, the plan shall include proposals for the provision of additional abatement and/or operational controls to further reduce emissions, along with timescales for implementation.

We have consulted with Natural England who are happy that the installation will not have an adverse impact at the SSSI.

The Habitats Regulation Assessment (HRAS) Stage 1 and 2, and Appendix 4 assessment, as found on the public register, show further details.

2. Thermal Discharge to water

The River Weaver is a European Eel migratory route, and also supports Water Voles and Code 2 species.

The application includes proposals to continuously discharge the CCU cooling waters into the River Weaver Flood Course via Outfall 11 with the occasional additional discharge of the Combined Heat & Power (CHP) plant cooling waters when the normal outfall of Outfall 5 is undergoing maintenance.

The discharge from Outfall 11 is directed by a levee (a man-made water diversion wall) which ensures the discharge travels over the weir 4m downstream of Outfall 11 and travels down the River Weaver Flood Course. As a result the risk assessment carried out is a simple assessment which assumes full instantaneous mixing over the weir.

CCU discharge only

The operational nature of the cooling system utilises variable cooling water flows, inlet and outlet temperatures and temperature differences (ΔT) and an assumed fixed thermal heat load of approximately 10.5MW from the CCU plant. The maximum possible heat load expected from the CCU plant is 13 MW and the maximum output temperature achievable by the heat exchanger is 38°C.

The worst case operational scenario would be maximum ΔT (35°C) to the cooling water when assuming the maximum assumed fixed thermal heat load (13 MW) and a maximum exit temperature of 38°C.

Using current understanding of the Q95 flows of the River Weaver Flood Course ($1m^3/s$ upstream of outfall 11) and the worst case operational scenario as described above, no flows from the CCU plant will result in a temperature uplift to the River Weaver in excess of 3°C (as required by the Water Framework Directive).

As a result the following limits and conditions have been added into table S3.2 of the permit:

Table S3.2 Point Source emissions to water (other than sewer) – emission limits and monitoring requirements						
Emission point ref. & location Note 1	**Parameter**	**Source**	**Limit (incl. unit)**	**Reference period**	**Monitoring frequency**	**Monitoring standard or method**
W4 Note 4 Via outfall 11 to River Weaver Flood Course	Temperature	Water from the Carbon Capture and Utilisation (CCU) plant cooling and compression system	Maximum 35°C incremental increase (ΔT) (to River Weaver input water ambient temperature)		Continuous	As described in the application
Note 4: The emission limits apply to a plant which has a maximum thermal load / cooling demand of 13 MW						

The discharge of the CCU plant cooling waters alone to the River Weaver Flood Course at the Q95 flows would not result in an increase to the rivers ambient temperature in excess of 3°C (as required by the Water Framework Directive), therefore we conclude there would not be an adverse impact upon the protected species found in the River Weaver Flood Course. This is based on a maximum thermal load/cooling demand from the CCU plant of 13 MW, which will be validated by response to Improvement Condition IC 19:

IC 19	**Confirmation of the maximum cooling demand of the CCU plant on the River Weaver cooling water** The operator shall submit a written report to the Environment Agency. The report must contain details of the outcome of monitoring and calculation of the thermal load/cooling demand of the CCU plant on the River Weaver cooling water, and must establish the maximum recorded value. The notification requirements of condition 2.4.2 will be deemed to have been complied with on submission of the report.	3 months after the activity AR5 in table S1.1 is successfully commissioned.

CCU & CHP

The discharge of diverted CHP plant cooling waters alongside the CCU plant cooling water discharge via Outfall 11 to the River Weaver Flood Course at the Q95 flows has the potential to increase the rivers ambient temperature in excess of 3°C and so could potentially have an adverse impact upon the protected species found in the River Weaver Flood Course. As the diversion of the CHP plant cooling water effluent to Outfall 11 is an emergency situation a calculation based limit has been included into the permit, and if required, the cooling water discharge from the CCU plant will be reduced to ensure that an increase to the rivers ambient temperature does not exceed 3°C:

Table S3.2 Point Source emissions to water (other than sewer) – emission limits and monitoring requirements						
Emission point ref. & location Note 1	**Parameter**	**Source**	**Limit (incl. unit)**	**Reference period**	**Monitoring frequency**	**Monitoring standard or method**
W4	Flow	Water from the Carbon Capture and Utilisation (CCU) plant cooling and compression system (when the CHP cooling water is also diverted to Outfall 11)	-	-	Continuous	Determined by difference based on a flow totaliser
W4 Via outfall 11 to the River Weaver	Temperature		TBD dependent on calculations using environmental conditions as agreed in the application and ensuring the uplift of the River Weaver ambient temperature is <3°C.	Daily averages (when in use)	Continuous (when in use)	Increase to the ambient temperature of the receiving water course from the CCU and CHP discharge to be <3°C and calculated using case by case environmental conditions: • Ambient river temperature • Q95 / flow gauge data for the River Weaver Flood Course upstream of the discharge • Cooling water exit temperatures • Cooling water flow rates • Thermal load of plant on cooling water; as agreed in the application.

We have been made aware that the operator have applied for an increase to the flows in their abstraction licence for this site. The granting of this licence may have the potential to impact upon the current risk assessment carried out for the discharge of cooling waters into the River Weaver Flood Course (such as reduced flow upstream of Outfall 11 in the flood course). If the River Weaver Flood Course Q95 flow is confirmed to be <1m^3/s upstream of Outfall 11 then a variation application for this permit must be made, which includes a revised risk assessment for the emission of cooling water from the CCU plant using the new Q95 flow rate.

3. Emissions that do not screen out as insignificant

Ammonia & Nutrient Nitrogen deposition from emissions to air

Please see comments under heading **'biodiversity, heritage, landscape and nature conservation'** above.

Total Nitrosamines and Nitramines emissions to air

Whilst the submitted emissions to air risk assessment report and associated modelling files (for Scenario 1) show that emissions to air of Total Nitrosamines and Nitramines could exceed the (preliminary) long term EAL for N-Nitrosodimethylamine (NDMA) of 0.2 ng/m^3 at two human receptors (marginally greater than 100%), this risk assessment is overly conservative and not representative of the expected emissions of these substances from the Carbon Capture Plant Absorber Stack (emission point A11).

The amine chemistry module of ADMS used in the modelling of emissions to air takes into account atmospheric concentrations of NO_x and ozone (O_3) to determine photolysis rates on an hourly basis. The release of amines to the air leads to formation of substances such as nitrosamines, nitramines (Nielsen et al. 2010[i], 2011a[ii],b[iii]) and other non-toxic products such as imine or isocyanic acid (Bunkan et al. 2014[iv]).

Nitrosamines and nitramines are carcinogens. Whilst there is toxicity data available for a few of the more generally researched substances (e.g. the nitrosamine drinking water contaminant N-nitrosodiethylamine - NDMA), the environmental toxicity of many of the other individual compounds is not well understood (SEPA 2015[v]).

Additional amine degradation products can also be released from the stack e.g. directly-emitted nitrosamines that result from the interaction between amine-based solvents and other pollutants. It has been reported that oxides of sulphur (SO_X) and NO_2 reacting with amine solvents can form numerous degradation products, including nitrosamines and nitramines.

A secondary amine such as DMA forms a stable nitrosamine that does not further dissociate. However, the debate whether the nitrosamine formed from MEA (a primary amine) is a stable product or not is still ongoing (Manzoor et al. 2017). Despite being a primary alkyl amino radical, it has been observed that MEA could form a thermally stable nitrosamine contradicting various studies (Angove et al. 2010[vi], Karl et al. 2012[vii]), however this is likely from the MEA degrading to secondary amines such as DEA which will then be nitrosated to NDELA.

The Carbon Capture and Usage Plant at the Winnington Sodium Carbonate Manufacturing Site will be using MEA as the capture solvent and hence only degraded solvent is likely to produce emissions of nitrosamine from the absorber stack. The degradation of the MEA will be minimised by process controls such as thermal solvent reclamation, solvent temperature controls, minimising oxides of Nitrogen (NO_x) and oxides of Sulphur (SO_x) concentrations in the flue gas input and those found in the process monitoring table (S3.5) of the permit. Additionally, the use of a flue gas scrubber and demister on the Absorber Stack will absorb and reduce any residual emissions.

The emissions to air risk assessment and modelling files submitted (Scenario 1 of the report) have made a very conservative assumption that all of the amines emitted (MEA, EA and DMA) will be DMA (a secondary amine) at a concentration of 20 mg/m^3, and have modelled as such. This model predicts an annual mean Process Contribution (PC) of total nitrosamines and nitramines (as NDELA) which exceeds the long term EAL for total nitrosamines and nitramines (by marginally greater than 100**%)** at consultant receptor HR3 and at the dwelling at NGR SJ6471775336.

However the more realistic modelling of emissions, supported by the manufacturers guaranteed emissions data, of a concentration of DMA (2 mg/m^3) would mean the annual mean PC of total nitrosamines and nitramines (as NDELA) would be 10% of that predicted by modelling scenario 1 and would not predict an exceedence of the long term EAL for nitrosamines and nitramines (as NDELA).

Improvement conditions IC13 – IC16 are included into the permit to validate the above assumptions.

Thermal discharges of cooling waters via Outfall 11 from point source emissions W2 and W4

Please see ‘Emissions to Water’ section under the ‘Biodiversity, heritage, landscape and nature conservation heading above’.

4. Raw Materials

We have included a DEA contamination limit to the MEA listed in the raw materials table S2.1 of 0.2%.

DEA is a known secondary amine contaminant in the production of MEA, due to the higher likelihood of degradation product formation from secondary amines in this process we have set a specification for the maximum amount of DEA present that we understand is achievable.

5. Pre-Operational Conditions

PO 01 – Intensive Monitoring Exercise 1 – Plan

This pre-operational condition requires the operator to set out a plan which proposes for a period of intensive isokinetic sampling and monitoring of the emissions to air from emission point A11. This plan is required to establish the emission concentrations from the expected emissions to air from the CCU plant.

PO 02 – Commissioning – Plan

This pre-operational condition requires the operator to submit a commissioning plan for the CCU plant, the plan must include proposals for an established operational envelope, i.e. range of temperatures, flowrates, solvent concentrations, capture rates etc the plant will operate within and associated process controls to ensure this.

PO 03 – Establishing baseline reference data

This pre-operational condition requires the operator to submit a report which establishes borehole locations, parameters to be tested for the baseline reference data for the site as described in Section 8 of the submitted Site Condition Report.

6. Improvement Conditions

IC12 - Commissioning Plan - Report

This improvement condition requires the operator to submit a report which requires the operator to summarise the environmental performance of the Carbon Capture Plant against the process controls and procedures laid out in the commissioning plan required by pre-operational condition PO 02, and also against the conditions of the permit and any additional procedures highlighted in the commissioning phase.

IC13 – Using the process to control solvent degradation and hence emissions to air of ammonia

Emissions of ammonia to air from the process are directly proportionate to the degradation of the solvent used. The operator proposes to use process controls to ensure that solvent degradation is minimised and thus ammonia emissions stay below the ELV set in the permit. This improvement condition requires the operator to submit a report which contains the results of a review of the effectiveness of using the process to control solvent degradation and hence emissions to air of ammonia.

IC14 - Intensive Monitoring Exercise 1 – Report

This improvement condition requires the operator to submit a report which summarises the outcome of the intensive period of monitoring carried out as a result of the plan agreed in PO 01.

IC15 - Intensive Monitoring Exercise 2 - Plan

This improvement condition requires the operator to submit a long term monitoring plan for emissions to air from the absorber stack, based on the results obtained as required in pre-operational condition PO 01 and the report submitted as required by improvement condition IC14.

IC16 - Intensive Monitoring Exercise 2 - Report

This improvement condition requires the operator to submit a report which use emissions monitoring data from the first year of operation to compare to the assumed concentrations used in the emissions to air impact assessment submitted in the application.

For those substances not included, or showing to be at concentrations higher than those assumed, in the emissions to air impact assessment submitted in the application this IC requires the operator to assess these the potential impact of these emissions to human health and habitats of each parameter using the H1 methodology.

Where EALs for emitted substances are not available on the current published EAL list on gov.uk then a substance that most closely represents the substance of interest should be used. In the absence of a suitable candidate parameter from the published list, then the hierarchy for the derivation of new Environmental Assessment Levels (EALs) to air document should be used.

In the event that the impact assessment shows that an environmental standard or permit ELV can be exceeded the improvement condition requires the operator to submit a plan (with implementation timescales/dates) which proposes additional abatement and/or operational controls.

IC17 – Black Start Condition for OCGT LCP

In the event of a black out National Grid would call on combustion plant to operate and may require them to do so outside their permitted conditions. National Grid have dedicated black start plant and they are permitted to run as such but this scenario is relevant to the rest of the large combustion plant which could be called depending on the circumstances.

A risk assessment in the form of air quality modelling will be provided by the operator. If the modelling demonstrates that no significant impacts are likely, the plant can operate under condition 2.3.11. This conditions allows the hourly ELVs for plants operating under a black start instruction to be discounted for the purpose of reporting. We would also require there to be a procedure in place for minimisation of emissions in the case of a black start event and for reporting in the event of a black start. This modelling and the procedures have not been agreed in advance of the issue of this variation and therefore a condition linking back to an improvement condition have been included in the permit.

IC18 – Monitoring location validation

It is now a requirement to include this improvement condition into all permit applications and/or variations that involve new stack monitoring in order to ensure that air monitoring locations meet the requirements of BS EN 15259

IC19 – Validation of the maximum cooling demand of the CCU plant on the River Weaver cooling water

The maximum thermal heat load/cooling demand of the CCU plant is currently assumed, as the emissions to water compliance limits (no flow limits and a ΔT limit of 35°C) are based on the maximum (assumed) thermal heat load this figure needs to be validated.

This improvement condition requires the operator to submit a report that details the outcome of monitoring and calculation of the thermal load/cooling demand of the CCU plant on the River Weaver cooling water, and must establish the maximum recorded value.

7. Operating Techniques and BAT assessment

General Operating Techniques

In the absence of published Best Available Techniques Conclusions (BATc) for Carbon Dioxide Capture, we have reviewed the techniques used by the operator against the "MAXIMISING THE EFFECTIVENESS OF POST COMBUSTION CO2 CAPTURE SYSTEMS"[ix] and "UK TWG 18 Submission for Combustion Sector BRef Note Revision" documents, as the basis of our Bat assessment.

Along with reviewing against the relevant points from the draft "BAT Review for New-Build and Retrofit Post-Combustion Carbon Dioxide Capture Using Amine-Based Technologies for Power and CHP Plants Fuelled by Gas and Biomass as an Emerging Technology under the IED for the UK" that is currently being drafted.

We have considered the following:

Overall performance

Including emissions and environmental performance, suitability for required duties, capture rates and energy use.

BAT justification of overall technology considering:

i. <u>Overall technology choice (i.e. pre or post combustion, retrofit, oxyfuel) against emerging technologies such as membranes</u>

The proposed technology (post combustion capture) *has been selected in preference to alternative capture technologies for the following reasons:*

- *It is a commercial scale capture technology capable of compliance with EU and UK environmental regulations;*
- *the availability of on-site power and heat sources from the CHP Energy plant to power the CO2 capture plant;*
- *precision in respect of CO2 output and quality controls;*
- *the modular nature of the technology and relatively small developmental footprint, and*
- *the very limited nature of emissions to air and water*

ii. <u>Selection of specific solvent(s) (see solvent section) used as basis for the application and consequences for emissions to atmosphere and other environmental impacts</u>

Monoethanolamine (MEA) is the solvent of choice for this proposal for a few reasons:

- The solvent is relatively benign and widely used for other purposes and so readily available at reasonable costs
- Moderate stability (compared to other amine solvents) and resistance to thermal degradation, which allows thermal reclamation to be easily used
- The pure material does not form stable nitrosamines
- Liquid at all relevant temperatures
- Degradation to secondary (and tertiary) amines (which do form stable nitrosamines and nitramines) are expected to be easily controlled by the process

iii. <u>Capture efficiency, including at varying load and during start/stop sequences</u>
The proposed Carbon Capture Unit will capture approximately 85% of the flue gas diverted from the CHP plant (11%).

The proposed Carbon Capture plant will not capture Carbon Dioxide during the start/stop sequences which we have accepted as BAT for this site as the Capture Plant is not designed to capture as much Carbon Dioxide as possible, only as much as is required for use in the nearby Sodium Bicarbonate plant.

iv. CO$_2$ specifications and suitability for intended and future storage

The Carbon Dioxide captured will be cleaned and dehumidified to the EIGA food grade standard before being transported (by pipeline) to the nearby Sodium Bicarbonate plant.

The proposed CCU plant will generate approximately 115 tonnes per day of liquid Carbon Dioxide. This will be stored in 3 x 200 tonne storage tanks, until it is conveyed to the Winnington CHP Site for use in the sodium bicarbonate manufacturing process. Each tank will be c.4m in diameter and c.23m long. A refrigeration unit, controlled by the CO_2 pressure in the CO_2 condenser, supplies the matching refrigerator capacity. The liquid CO_2 is stored under pressure of approximately 15-18 bar(g) and a corresponding temperature of approximately -27°C / -21°C.

v. Effect of plant size vs number of units

The capture plant has been designed to capture the amount of CO_2 required for use in the sodium bicarbonate plant.

The flue gas scrubber (gas cooler) will be c 3.4m in diameter and 11m high.

The absorber column will have a c. 3.6m diameter and maximum height of c. 50m above ground level.

The stripper column will have a c. 1.6m diameter and maximum height of c. 27.5m above ground level.

vi. Effective overall design with respect to thermal integration, based on overall plant thermal efficiency with capture, the Electricity Output Penalty for CO_2 capture and compression, taking into account use of low grade heat where feasible and appropriate use of auxiliary plant

Introduction

Winnington CHP is an industrial scale CHP producing steam and electricity and consuming natural gas. It was built in year 2000 to supply energy to two large chemical sites but in 2014, one major plant on one of those sites closed. As a result, Winnington CHP had to be reconfigured (including a new steam turbine) but it is on balance “on the large side” for the range of energy demands placed upon it.

Impact of CCU plant in terms of energy flows

The CCU plant requires about approximately 8.25te/hour steam at a rate of 40,000 tonnes CO_2 captured per year. This equates to approximately 5.7% of the total generated steam demand.

In addition to steam the CCU plant also consumes about 10,800 MWh electricity per year.

How the CHP plant efficiency is calculated

The CHP plant have a complex model that calculates gas input, electricity output and plant efficiency on a very accurate basis for any site steam demand. It is used every day and validated on a regular basis.

To calculate the increase in efficiency for the CHP, a base case was input into the model and then re-visited with the additional 8.25 tonnes per hour steam demand for the CCU plant. The CHP plant efficiency was compared both cases, and there was an actual 0.3% efficiency increase when the CCU plant operates.

CHP Efficiency

0.3% efficiency gain sounds trivial but it’s not. It’s 0.3% across the entire steam demand not just the additional tonnes.

The model shows that:

Looking at the CHP model over a calendar year, the average “baseload” therms gas per tonne steam is 50.53.

The impact of adding 8.25 tonnes per hour steam to the baseload steam demand is that the additional steam is generated at 28.3 therms gas per tonne steam. The carbon capture steam is therefore being generated at just 56% of the gas consumption related to the baseload.

At the same time, the additional tonnes of steam also generate electricity and will produce an additional 4,910MWhr electricity. This is approaching half the demand of the CCU plant.

Further there are times in the year when steam demand drops and when this occurs steam is vented. Having this additional steam demand cuts the volume vented by up to 8.25 tonnes per hour when it takes place. It is anticipated that this will save a further 10% of an already very low gas consumption. On this basis the expected gas consumption will actually be 25.47 therms per tonne steam i.e. almost half the cost and twice as efficient as the baseload.

Energy Use in the CCU Plant

Whilst the information provided in the permit variation identifies the energy consumption of the CCU plant, this energy is being used to produce CO_2 for supply to the adjacent sodium bicarbonate plant. This will replace CO_2 that has traditionally been produced elsewhere and transported to the site.

The energy input is therefore being consumed to generate a useful product which would otherwise have had an associated energy demand at the site it was produced. This is unlike a carbon capture for geological storage plant where the energy use would be seen as an energy penalty.

Cooling Methodology

The proposed plant will use "once through" cooling using water from the River Weaver. This is considered the most energy efficient way of cooling and so is BAT.

Summary

- The increased steam demand for carbon capture increases the efficiency of the CHP.
- The additional tonnes of steam are generated using about half the energy compared to the baseload steam demand (which is already efficient).
- The steam also generates additional "free" electricity which provides almost half of the electricity needed for the carbon capture plant.
- Attaching a carbon capture to an appropriately sized CHP is extremely efficient and is a major reason why the plant is being built.
- Once through cooling water system being used is BAT.

vii. Solvent selection

BAT justification of the selected solvent, considering the following based on the composition and performance of the solvent inventory in the plant in normal long-term service (i.e. after at least one year of continuous operation):

a) Known and potential toxicity for the environment of the solvent and its degradation products that are formed due to the presence of NO_x and other factors

Monoethanolamine (MEA) is readily biodegradable and has no direct adverse effects human health, animals and vegetation. In contrast other amine solvents are toxic and not easily biodegraded compared with MEA.

The compounds which have the greatest health and environmental risk w.r.t the Carbon Capture Plant are nitrosamines due to their carcinogenic properties.

Primary amines (such as MEA) have the lowest risk with regards to forming Nitrosamines,

b) Emissions to air of amine and amine degradation products including ammonia (and taking into account any ammonia slip from SCR)

Reducing emissions of amine compounds and their degradation products can be achieved through the use of two main approaches: minimisation/removal of precursor species and/or post-generation removal from the generation from emissions to air and to water.

Treatment of solvent/wash system circuits to minimise/remove precursor species can be achieved through methods including thermal reclaiming, ion-exchange, electrodialysis, ultraviolet radiation and the addition of inhibitors.
Thermal reclamation can remove all degradation products, heat stable salts and non-volatile impurities into reclaimer waste which can be disposed of offsite by licenced

companies. A study by IEAGHG assumed an amine recovery rate of 85-95% from thermal reclamation[8]. Thermal reclaiming systems use elevated temperatures, which have been reported to cause some corrosion inhibitors to degrade or be ineffective, although this is only an issue if corrosion inhibitors are being used at the plant.
The other methods of minimisation/removal of precursor species mentioned above either have prohibitively high costs, less effective removal efficiencies or very limited data regarding their use and/or effectiveness.
Most amine solvents and their associated degradation compounds are water soluble and so the use of aqueous scrubber systems after the absorber column is an available method for abating any unwanted emissions.

The proposed CCU plant will incorporate two stages for water scrubbing of the unwanted flue gas and a demister prior to release to the atmosphere. The CO_2 and flue gas components remaining after the absorber and NO_x flash unit will be water scrubbed at the top of the absorber column to remove any amine that may be in aerosol form and will pass through the demister to reduce potential for fog and mist formation, before the cleaned, demisted and CO_2-depleted flue gas is released to the atmosphere. Wet scrubbing is considered BAT for reducing emissions of VOCs ([10, LVOC BAT Ref Doc]) and therefore the abatement to be used at the CCU plant is considered BAT.

Degraded amines and other compounds will also be removed from the process via the reclaimer as part of the liquid reclaimer waste. Some of the returning lean amine solution from the stripper will be slipstreamed through a reclaimer unit to recover degraded amines and other compounds which will be disposed of at appropriately licenced facilities. We consider this to be BAT for the process.

c) Further reactions of the amine and amine degradation products in the atmosphere to form, e.g. nitrosamines
d) Primary amines (such as MEA) have the lowest risk with regards to forming Nitrosamines, Solvent reclaimability and factors impacting this

   MEA is easy to reclaim thermally and is resistant to thermal degradation.
e) Wastes (wastewater/reclaimer sludge) produced and disposal/recovery/treatment options

Waste	***Nature***	***Expected amount (max) per annum (8,322 hours)***	***Storage***	***Disposal/Recovery Route***
Activated Carbon (used in carbon filter)	*Carbon Blend #2*	*0.37 tonnes*	*Stored in sealed containers until removed from site*	*Non-hazardous waste disposal/recycling by licenced offsite facility*
Activated alumina dessicant (used in dehydrator)	*Puriblend #1, Puriblend #6*	*0.41 tonnes*	*Stored in sealed containers until removed from site*	*Non-hazardous waste disposal/recycling by licenced offsite facility*
Activated Carbon (used in MEA filter)	*Carbon Blend #1*	*5.05 tonnes*	*Stored in sealed containers until removed from site*	*Non-hazardous waste disposal/recycling by licenced offsite facility*
Process water from flue gas scrubber	*99.99% H_2O, 0.01% CO_2*	*16,650 tonnes*	*None*	*Non-hazardous – discharged to river via SUDS*
Reclaimer waste	*Liquid – 45% MEA, 25% Heat Stable Salts (HSS), 15% H_2O, 8% O_2, 4% NaOH,*	*92 tonnes*	*IBC within bunded area*	*Hazardous waste disposal/recycling by licenced offsite facility*

	3% trace compounds			

f) Solvent consumption in long-term use

From the mass flow of MEA given in the Air Quality assessment…the estimated maximum annual flow of amine emissions (MEA, DMA, ethylamine, nitrosamines and acetaldehyde) will be approximately 12.6 tonnes over the expected 8,322 hours of operation.

Other studies have stated MEA losses of approximately 0.01 – 0.8 kg/tonne CO_2 removed without a water wash, or 0.01 – 0.03 kg/tonne CO_2 removed with a water wash system[viii].

An annual limit for Total Amines (primary, secondary, tertiary and nitrosamines as agreed in table S3.1f(i(&(ii)) of 13 tonnes has been included into table S3.4 of the permit to limit the mass release of total amines to those assessed in the emissions to air risk assessment and the maximum expected annual flow, however the average expected flow is expected to be more in line with the 0.01 – 0.03 kg/tonne CO_2 removed which equates to 1.2 tonnes per annum (tpa) (with the expected capture of 40,000 tpa of CO_2.

Acetaldehyde has not been included in this definition as it is not an amine compound.

g) Electricity Output Penalty consequences for the capture plant (See above 'overall design' section)

h) Availability and cost of the fresh solvent

MEA is a low cost, widely available solvent.

i) Consequences for the relative capital cost of the plant

The operation of the proposed CCU plant will in fact increase the thermal efficiency of the gas-fired CHP plant by 0.3%, and the capture plant is actually a CO_2 production plant producing a product and therefore capital costs are off-set by this.

Given the above we consider that the use of MEA as the solvent is BAT for this process.

viii. Emissions to air

a) Abatement technologies considered and used, e.g. water wash, acid wash, demisters

The proposed CCU plant will incorporate two stages for water scrubbing of the unwanted flue gas and a demister prior to release to atmosphere. The CO2 and flue gas components remaining after the absorber and NO_x flash unit will be water scrubbed at the top of the absorber column to remove any amine that may be in aerosol form and will pass through the demister to reduce potential fog and mist formation, before the cleaned, demisted and CO2 depleted flue gas is released to the atmosphere.

Aerosols will be minimised but there can be no guarantee that there will be no aerosols present in the flue gas following scrubbing and demisting. As a result stack monitoring must be carried out iso-kinetically and ELVs met, both of which have been included as requirements of the permit.

b) Assessment of degradation products during operation – solvent process monitoring on and off line

Ammonia and acetaldehyde are degradation products formed from oxidative processes, primarily taking place around the absorber sump and packing.

The assessment has examined the air quality impacts arising from degradation products, nitrosamines and nitramines, produced by the reactions of amines with other species in the exhaust gas and released from the absorber tower.

ix. Water use

BAT justification consideration of water use in the LCP and the carbon capture process:

a) abstraction for once-through cooling and consumption for process or cooling towers

The site will be operating a once-through cooling process as described below.

b) sensitivity of receiving environment for returns including low flow and temperature

See emissions to water section of the Key Issues

c) water recovery options and minimisation of use

There will be limited use of freshwater at the CCU plant.
Cooling in the CCU plant will be via a closed-circuit system that will use a diluted propylene glycol/water mix as the fluid. This fluid will pass through several heat exchangers in parallel and the final warm glycol fluid itself will be cooled in an exchanger which will have river water from the River
Weaver as the coolant. The river water will not come into contact with the glycol fluid as it will be an indirect cooling system. The cooled glycol will recirculate around the CCU plant and the warmed river water will be returned to the River Weaver flood course.
For the flue gas scrubber, water will be pumped from the base of the unit through one of the glycol exchangers and then back to the flue gas scrubber. This cooled return will cool the incoming flue gas from the CHP condensing water vapour. Excess condensate will be will be discharged into the site drains and ultimately discharge via outfall 11 into the River Weaver flood course. The water from the flue gas scrubber drain will be 99.99 % w/w water and 0.01 % w/w CO_2.

x. Other Considerations

a) Lessons learned from previous CCS trials and implications for chosen approaches

Ferrybridge pilot plant has been considered during the development of the CCU plant at Winnington. It has been suggested from this pilot plant that a single stage water wash may not be sufficient to reduce MEA emissions to low levels. This is said to be because of the presence of MEA in the form of aerosols, which can't be removed by a standard water wash.

As a result *the proposed CCU plant will incorporate two stages for water scrubbing of the unwanted flue gas and a demister prior to release to the atmosphere.*

b) CO_2 impurities and potential of combined effects with other sources

After the gas from the stripper is cooled, it is then water scrubbed to remove any amine that may be in aerosol form. The CO_2 is then compressed, dehydrated, filtered and cooled using anhydrous ammonia to achieve EIGA standards, as described below. At this stage the gaseous CO_2 is converted to liquid format before finally being sent to the proposed storage tanks shown on Figure 2.
The gas is compressed in two stages to approximately 15-18 bar (g) by the CO_2 compressor. Prior to liquefaction, the gas is dried in the dehydrator. Regeneration of the dehydrator is done automatically by electrical heating and use of dry purge gas from the CO_2 condenser. Traces (if any) of acetaldehyde, a degradation product that can form in the absorber sump and packing, are also removed in the dehydrator. The CO_2 gas then passes through an activated carbon filter for removal of any odorous substances such as amines and aldehydes. The CO_2 gas passes through a reboiler to remove the last non-condensable gases. It is then condensed in a CO_2 condenser, where the non-condensed gases are purged off. Finally, the condensed CO_2 is led through the purification column to an insulated storage tank. During this process the liquid CO_2 will be continuously analysed to ensure that it conforms to EIGA standards as described in Doc 70/17[5]. The testing locations are expected to be at the following parts of the process: transfer of process fluid to stock; all three stock tanks' discharged fluid; tanker filling; and transfer of CO_2 to Sodium Bicarbonate Plant. The CO_2 produced has a purity higher than 99.99% (v/v) and fulfils quality standards as a food/beverage ingredient.

c) Amenity issues – noise, dust and odour, e.g. noise can be an issue from CO_2 compression

Noise and Vibration

An assessment of the expected impact of noise from operation of the proposed CCU plant (including
commissioning) is provided in Appendix F of the application. This identifies the main noise sources and nearest noise sensitive receptors (NSRs), characterises the noise sources, assesses its potential impact and considers those impacts in the context of relevant BAT criteria. Details of noise monitoring for the purpose of establishing the baseline levels are

also provided. The assessment was informed by available data on similar plant items to be installed within the CCU plant.

The results of the assessment indicate that significant adverse noise or vibration effects will not be expected as a result of operating the proposed CCU plant.

Noise and vibration effects from the operation of the proposed CCU plant are also considered within the ERA included in Appendix D of the application. The ERA has followed the format of EA guidance and conclude that no significant noise risks are expected from the CCU plant.
We agree with this conclusion.

d) Visibility – e.g. expected vapour plume visibility

A visible plume is likely from the absorber stack of the proposed CCU plant, as the stack emission will be relatively cool and wet due to the water scrubber. Stack gas reheat is possible but it comes with an energy penalty. However, the proposed development area for the CCU plant is in the centre of a large industrial estate so it is considered unlikely to result in significant visual impact, and it would not be energy efficient to re-heat the stack gases.

8. Operating techniques for emissions that do not screen out as insignificant

Whilst the use of a water wash for ammonia emissions is not classed as BAT, the operator has confirmed that they are not attempting to rely on the water wash to control ammonia emissions.

The current understanding is that as the evolution of ammonia is related to the degradation of the solvent, the process controls in place for the plant will be sufficient to be able to keep solvent degradation minimised to a level where the emissions to air will be below the ELV for ammonia in the permit.

As a result we have included IC 13 into the permit which requires the operator to review the situation following the intensive monitoring period and propose additional abatement if necessary.

IC13	**Using process controls to minimise solvent degradation to control emissions to air of ammonia - Review & Report** Submit a written report to the Environment Agency for technical assessment and approval. The report must contain the results of a review of the effectiveness of using process controls to minimise solvent degradation to control emissions to air of ammonia, using the data acquired from the emissions to air monitoring of ammonia concentrations from emission point A11 (as found in table S3.1f(i) & (ii), emission point A11). If the results show that process controls alone are not sufficiently effective for the prevention of ammonia evolution down to compliance limits (or lower) then the report shall contain a plan which includes proposals for further abatement of ammonia, including an emissions and process monitoring plan, reporting proposals and implementation dates. The report must contain dates for the implementation of any individual measures. The notification requirements of condition 2.4.2 will be deemed to have been complied with on submission of the report (and plan). You must implement the plan as approved, and from the date stipulated by the Environment Agency.	3 months after the activity AR5 in table S1.1 is successfully commissioned.

Decision checklist

Aspect considered	Decision
Receipt of application	
Confidential information	A claim for commercial or industrial confidentiality has not been made.
Identifying confidential information	We have not identified information provided as part of the application that we consider to be confidential.
The facility	
The regulated facility	We considered the extent and nature of the facilities at the site in accordance with RGN2 'Understanding the meaning of regulated facility', Appendix 2 of RGN 2 'Defining the scope of the installation', Appendix 1 of RGN 2 'Interpretation of Schedule 1', guidance on waste recovery plans and permits. The extent of the facilities are defined in the site plan and in the permit. The activities are defined in table S1.1 of the permit.
The site	
Extent of the site of the facility	The operator has provided plans which we consider are satisfactory, showing the extent of the site of the facility. The plans are included in the permit.
Site condition report	The operator has provided a description of the condition of the site, which we consider is satisfactory. The decision was taken in accordance with our guidance on site condition reports and baseline reporting under the Industrial Emissions Directive. We have included a pre-operational condition into the permit which requires the operator to establish the reference baseline data and locations agreed with the Environment Agency as suggested by the applicant in section 8 of the Site Condition Report.
Biodiversity, heritage, landscape and nature conservation	The application is within the relevant distance criteria of a site of heritage, landscape or nature conservation, and/or protected species or habitat. We have assessed the application and its potential to affect all known sites of nature conservation and protected species or habitats identified in the nature conservation screening report as part of the permitting process. We consider that the application will not affect any of the following sites of nature conservation or protected species or habitats identified: • Oak Mere (SAC) • West Midlands Mosses (SAC) • West Midlands Meres and Mosses Phase 1 & 2 (Ramsar) • Whitton Lime Beds (SSSI) • Marshall's Arm, Hartford (LNR) • Owley Wood (LWS & AW) • Barnton Cut Wood (LWS) • Ashton's and Neumann's Flashes (LWS)

Aspect considered	Decision
	• Fury Tip (LWS) • Bestway Wood, Gunners Clough and Nursery Wood (LWS) • Anderton Lime Bed (LWS) • Witton Flashes (LWS) • Marbury Lime Bed and Forge Pool (LWS) • Marston Flashes (LWS) • Hopyards Wood (LWS) • Marbury Big Wood (LWS) • Marston Meadows (LWS) • Kennel Wood (LWS) • Budworth Mere (LWS) • Beach Hill Wood (LWS & AW) • Weather Valley/Newbridge Pool (LWS) • Gunners Clough (AW) • Brakely Rough (AW) • Big Wood (AW) • European Eel Anguilla (protected species)* • Water Vole Arvicola (protected species)* • Code 2 (protected species)* * emissions to water protected species Please see the key issues section for further information. We have consulted Natural England on our Habitats Regulations and SSSI assessments, and taken their comments into account in the permitting decision.
Environmental risk assessment	
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.
Environmental risk	We have reviewed the operator's assessment of the environmental risk from the facility. The operator's risk assessment is satisfactory. See key issues for further details Emissions to air The assessment shows that, applying the conservative criteria in our guidance on environmental risk assessment which included additional similar methodology, in the form of the use of the ADMS Amine Chemistry Module, supplied by the operator and reviewed by ourselves, all emissions may be categorised as environmentally insignificant with the exception of: • Ammonia (see biodiversity section for details) • Annual NO_2, however the PECs will not exceed the environmental standard of 40 ug/m^3 • Hourly NO_2, however the PECs will not exceed the environmental standard of 200 ug/m^3

Aspect considered	Decision
	• Total Nitrosamines and Nitramines could exceed the (preliminary) long term EAL for N-Nitrosodimethylamine (NDMA) of 0.2 ng/m^3 at two human receptors <u>Emissions to water</u> The assessment shows that, applying the conservative criteria in our guidance on environmental risk assessment or similar methodology, supplied by the operator and reviewed by ourselves, all emissions may be categorised as environmentally insignificant with the exception of: Thermal discharges via Outfall 11, as shown on the plans in Schedule 7 of the permit, of both CHP and CCU cooling waters during River Weaver low flow periods (<1m3/s). Please see the key issues section for further information
Operating techniques	
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. CC is an emerging technology which currently has no published Best Available Techniques Conclusions (BATc) documents. As a result we reviewed the techniques used by the operator against the “MAXIMISING THE EFFECTIVENESS OF POST COMBUSTION CO2 CAPTURE SYSTEMS” and “UK TWG 18 Submission for Combustion Sector Bref Note Revision” documents, as the basis of our BAT assessment. Along with reviewing against the relevant points from the draft “BAT Review for New-Build and Retrofit Post-Combustion Carbon Dioxide Capture Using Amine-Based Technologies for Power and CHP Plants Fuelled by Gas and Biomass as an Emerging Technology under the IED for the UK”. The operating techniques that the applicant must use are specified in table S1.2 in the environmental permit. See Key Issues for further information.
Operating techniques for emissions that do not screen out as insignificant	Emissions of the following pollutants cannot be screened out as insignificant: <u>Emissions to air</u> • Ammonia at Witton Lime Beds SSSI - See <u>key issues</u> for further details • Nutrient Nitrogen Deposition at Witton Lime Beds SSSI (see Key Issues for further details) • Annual NO_2 at relevant human receptors, however the PECs will not exceed the environmental standard of 40 ug/m^3 • Hourly NO_2 at relevant human receptors, however the PECs will not exceed the environmental standard of 200 ug/m^3 • Total Nitrosamines and Nitramines could exceed the (preliminary) long term EAL for N-Nitrosodimethylamine (NDMA) of 0.2 ng/m^3 at two human receptors (see <u>key issues</u> for further details) <u>Emissions to water</u> • Thermal discharges via Outfall 11, as shown on the plans in Schedule 7 of the permit, of both CHP (diverted due to

Aspect considered	Decision
	maintenance of outflow 5) and CCU cooling waters during River Weaver low flow periods (<1m3/s). • Thermal discharges via Outfall 11, as shown on the plans in Schedule 7 of the permit, of the CCU plant cooling waters during River Weaver low flow periods (<1m3/s). We have assessed whether the proposed techniques are BAT. See key issues for further details The proposed techniques and 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 we consider them to represent appropriate techniques for the facility. The permit conditions ensure compliance with the draft 'BAT Review for New-Build and Retrofit Post-Combustion Carbon Dioxide Capture using Amine Based Technologies for Power and CHP plants fuelled by natural gas or biomass as an emerging technology under the IED for the UK'.
Operating techniques for emissions that screen out as insignificant	Emissions of the following pollutants have been screened out as insignificant, and so we agree that the applicant's proposed techniques are BAT for the installation: Emissions to air • Acetaldehyde, Carbon Monoxide, Ammonia at relevant human receptors • Annual mean Total Amine, against their derived EALs for EA (7.6ug/m^3_{LT}; 22ug/m^3_{ST}), DMA (7.6ug/m^3_{LT}; 22ug/m^3_{ST}) and MEA (5ug/m^3_{LT}; 15.2ug/m^3_{ST} which are more conservative than the PHE agreed EAL of 0.1mg/m^3_{LT}; 0.4mg/m^3_{ST}) • Acid deposition at all ecological receptors • Ammonia at all ecological receptors except for Witton Lime Beds SSSI • Nutrient Nitrogen Deposition at all ecological receptors except for Witton Lime Beds SSSI We consider that the emission limits included in the installation permit reflect the BAT for the sector.
Permit conditions	
Raw materials	We have specified limits and controls on the use of raw materials and fuels. MEA is considered BAT for this proposal, see key issues section for more information.
Pre-operational conditions	Based on the information in the application, we consider that we need to impose pre-operational conditions. We have included these to: • Ensure the submission of a sampling and monitoring plan for the newly included post-combustion carbon capture plant • Ensure the submission of a commissioning plan for the newly included post-combustion carbon capture plant

Aspect considered	Decision
	• Establish baseline contaminant data for the site See key issues for further details.
Improvement programme	Based on the information on the application, we consider that we need to impose an improvement programme. We have imposed an improvement programme to ensure: • The submission of a report of the performance of the plant against the commissioning plan submitted as a requirement of pre-operational condition PO 02 • The submission of a report that contains the results of a review of the effectiveness of using the process to control solvent degradation and thus emissions to air of ammonia • The submission of a report on the outcome of intensive monitoring period required by pre-operational condition PO 01 • The submission of a long term monitoring plan based on the outcome of the results of IC14 • The submission of a report which must contain an emissions to air risk assessment in line with our guidance which is based on sampled and monitored emissions data from emission point A11 in table S3.1f(i) • The submission of a report containing a risk assessment demonstrating there is no significant environmental risk associated with black start operations of the OCGT LCP • The requirement to carry out tests to assess whether the air monitoring location from the CCU plant (A11) meets the requirements of BS EN 15259 • The requirement to validate the maximum thermal load/cooling demand of the CCU plant on the River Weaver cooling water See key issues for further details.

Emission limits	ELVs and equivalent parameters or technical measures [based on BAT] have been added for the following substances from the Post-combustion Carbon Capture Plant:
	
	• Emissions to air:
	  ○ Oxides of Nitrogen
	  ○ Carbon Monoxide
	  ○ Ammonia
	  ○ 2-ethanolamine (monoethanolamine, MEA)
	  ○ Dimethylamine (DMA)
	  ○ Total Nitrosamines and Nitramines (as NDMA)
	• Emissions to surface water:
	  ○ Temperature
	• Process Monitoring
	  ○ Colour of solvent
	
	It is considered that the proposed techniques and numeric limits described below will prevent significant deterioration of receiving waters, protected habitats and species and harm to human health. We have imposed these limits because either a relevant environmental quality or operational standard requires this.

<table>
<tr><th>Aspect considered</th><th>Decision</th></tr>
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Emissions to air:

Oxides of Nitrogen (based on LCP BATc requirements)

60 mg/m^3 – monthly mean of validated hourly averages
66 mg/m^3 – daily mean of validated hourly averages
120 mg/m^3 – 95% of validated hourly averages within a calendar year
55 mg/Nm^3 – yearly average

Carbon Monoxide (based on LCP BATc requirements)

100 mg/m^3 - monthly mean of validated hourly averages
110 mg/m^3 - daily mean of validated hourly averages
200 mg/m^3 - 95% of validated hourly averages within a calendar year
50 mg/Nm^3 – yearly average

Ammonia - 23 mg/Nm^3 (based on the figure used in modelling, taken from a manufacturers guarantee)
2-ethanolamine (monoethanolamine, MEA) – 20 mg/Nm^3 (based on rounding up the figure used in modelling (19.09 mg/Nm^3), taken from a manufacturers guarantee, and the class A VOC limit in ‘The Production of Large Volume Organic Chemicals (EPR 4.01)’ technical guidance note) The modelling predicted (using an emission concentration of 19.09 mg/Nm3) that the maximum long term Predicted Environmental Concentration (PEC) equals 3.1% of the EAL and the maximum short term PEC equals 40.5% of the EAL, allowing for the rounding up of the ELV.
Dimethylamine (DMA) – 2 mg/Nm^3 (based on the figure used in modelling, taken from a manufacturers guarantee)
Total Nitrosamines and Nitramines (as NDMA) – 0.05 mg/Nm^3 (based on the figure used in modelling, taken from a manufacturers guarantee)

Emissions to surface water:

W4 - CCU cooling water via Outfall 11

temperature – 35ºC incremental increase to River Weaver ambient temperature

W4 – CCU & diverted CHP cooling water via Outfall 11

Flow – Determined by difference based on a flow totaliser
Temperature – Increase to the ambient temperature of the receiving water course from the CCU and CHP discharge to be <3°C and calculated using case by case environmental conditions:

Ambient river temperature
Q95 / flow gauge data for the River Weaver Flood Course upstream of the discharge
Cooling water exit temperatures
Cooling water flow rates
Thermal load of plant on cooling water;

as agreed in the application for this variation.

</td></tr>
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Aspect considered	Decision

Monitoring	We have decided that monitoring should be added for the following parameters, using the methods detailed and to the frequencies specified in tables S3.1f(i) & (ii), S3.2 and S4.5:
	• Emissions to air (emission point A11):
	    o Oxides of Nitrogen
	    o Carbon Monoxide
	    o Sulphur Dioxide
	    o Oxygen
	    o Water Vapour
	    o Stack Gas Temperature
	    o Stack Gas Pressure
	    o Stack gas temperature
	    o Ammonia
	    o Acetaldehyde
	    o Total Amines (expressed as MEA)
	    o 2-ethanolamine (monoethanolamine, MEA)
	    o Methyl diethanolamine (MDEA)
	    o Diethanolamine (DEA)
	    o Ethylamine (EA)
	    o Dimethylamine (DMA)
	    o Morpholine (MOR)
	    o Piperazine (PZ)
	    o Monomethylamine (MMA)
	    o Total Nitrosamines and Nitramines (as NDMA)
	    o N-nitrosodiethanolamine (NDELA)
	    o N-nitrosodimethylamine
	    o N-nitrosomorpholine
	    o N-nitrosomethylethylamine
	    o N-nitrosodiethylamine
	    o N-nitrosodiisopropylamine
	    o N-nitrosodiisobutylamine
	    o N-nitrosodipropylamine
	    o N-nitrosodibutylamine
	    o N-nitrosopiperdine
	    o N-nitrosopyrrolidine
	    o N-nitrosodibenzylamine
	    o N-(2-hydroxyethyl)ethylenediamine (HEEDA)
	    o N-nitrosomorpholine (NSMO)
	    o N-nitrosopiperazine (MNPZ)
	    o Formaldehyde
	• Emissions to surface water (W4):
	    o flow
	    o incremental temperature
	• Process Monitoring Requirements (table S4.5)
	    o MEA purity (%) and concentration of individual degradation products (%)
	    o Percent active solvent
	    o Carbon dioxide loading
	    o Heat stable salts concentration in the solvent
	    o Soluble iron concentration in the solvent
	    o Colour of Solvent
	    o Soluble iron concentration (lean solvent after carbon bed)

Aspect considered	Decision
	○ Carbon dioxide loading (rich solution) ○ Degradation products – such as: expected primary secondary and tertiary amines, nitrosamines, nitramines (in amine solvent solution prior to reclaiming ○ Temperature of incoming cooling water These monitoring requirements have been imposed in order to validate emission assumptions made in the application and enable a long term monitoring plan to be established. We made these decisions in accordance with the draft 'BAT Review for New-Build and Retrofit Post-Combustion Carbon Dioxide Capture using Amine Based Technologies for Power and CHP plants fuelled by natural gas or biomass as an emerging technology under the IED for the UK', and the requirements of the LCP BAT conclusions document. Based on the information in the application we are satisfied that the operator's techniques, personnel and equipment have either MCERTS certification or MCERTS accreditation as appropriate.
Reporting	We have added and amended reporting in the permit for the following parameters: • Emission points A11 and W4 into table S4.1 • Table S4.5 to include reporting for the Post-combustion Carbon Capture Performance parameters We made these decisions in accordance with the draft 'BAT Guidance for New-Build and Retrofit Post-Combustion Carbon Dioxide Capture using Amine Based Technologies for Power and CHP plants fuelled by natural gas or biomass as an emerging technology under the IED for the UK', and the requirements of the LCP BAT conclusions document.
Operator competence	
Management system	There is no known reason to consider that the operator will not have the management system to enable it to comply with the permit conditions.
Growth Duty	
Section 108 Deregulation Act 2015 – Growth duty	We have considered our duty to have regard to the desirability of promoting economic growth set out in section 108(1) of the Deregulation Act 2015 and the guidance issued under section 110 of that Act in deciding whether to grant this permit. Paragraph 1.3 of the guidance says: "The primary role of regulators, in delivering regulation, is to achieve the regulatory outcomes for which they are responsible. For a number of regulators, these regulatory outcomes include an explicit reference to development or growth. The growth duty establishes economic growth as a factor that all specified regulators should have regard to, alongside the delivery of the protections set out in the relevant legislation." We have addressed the legislative requirements and environmental standards to be set for this operation in the body of the decision

Aspect considered	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.

Consultation

The following summarises the responses to consultation with other organisations and the way in which we have considered these in the determination process.

Responses from organisations listed in the consultation section

Response received from
Natural England
Brief summary of issues raised
As described in documents: **Appendix 3**
Summary of actions taken or show how this has been covered
Natural England are happy with our assessment. ICs have been included into the permit to validate the emission assumptions used in the emissions to air risk assessment modelling.

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[i] Nielsen et al., 2010. Theoretical Evaluation of the Fate of Harmful Compounds Post Emission. Tel-Tek. 2010

[ii] Nielsen et al., 2010 a. Summary Report: Photo-oxidation of Methylamine, Dimethylamine and Trimethylamine. Climit Project No. 201604 NILU OR 2/2011. NILU ISBN 978-82-425-2357-0. 2010

[iii] Nielsen et al., 2010 b. Atmospheric chemistry of 2-aminoethanol (MEA). Energy Procedia 4, 2245–2252. 2010

[iv] Bunkan, et al., 2014. Atmospheric gas phase chemistry of CH_2 NH and HNC a first-principles approach. J. Phys. Chem. A 118, 5279–5288. 2014

[v] SEPA 2015. Review of amine emissions from carbon capture systems, Version 2.01. 2015

[vi] Angove et al., 2010. CO_2 Capture Mongstad –Project B –Theoretical Evaluation of the Potential to Form and Emit Harmful Compounds, CSIRO Report. 2010

[vii] Karl et al., 2012. Study of OH-initiated degradation of 2-aminoethanol. Atmos. Chem. Phys. 12, 1881–1901. 2012

[vii] Spietz, Dobras, Wieclaw-Solny and Krotki, 2017. Nitrosamines and nitramines in Carbon Capture plants. Available online: https://www.degruyter.com/downloadpdf/j/oszn.2017.28.issue-4/oszn-2017-0027/oszn-2017-0027.pdf

[ix] Maximising The Effectiveness Of Post Combustion CO_2 Capture Systems. Refereed paper, Proc. GHGT7, Vancouver, Sep. 2004. J.R. Gibbins, R.I. Crane, D. Lambropoulos (Energy Technology for Sustainable Development Group, Mech Eng Dept, Imperial College London, SW7 2AZ, UK); C. Booth, C.A. Roberts (Fluor Ltd, Camberley, Surrey) and M. Lord (Alstom Power, Rugby, UK).