



Immingham Combined Heat and Power (CHP) Power Plant

Environmental Permit Variation Application
Main Supporting Document

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1. Non - Technical Summary

This document presents the supporting information for an Environmental Permit variation application under the Environmental Permitting (England and Wales) Regulations 2016 (as amended) ('the EP Regulations'), submitted on behalf of VPI Immingham ('VPI') to vary the Environmental Permit (reference EPR/BJ8022IZ) for the Immingham Combined Heat and Power (CHP) Power Plant (the 'Installation'). The Installation's location and Installation Site Boundary are provided in Figures 1 and 2 (Appendix A).

VPI intend to retrofit two trains of Post-Combustion Carbon Capture (PCC) plants treating the flue gas emitted from the Installation's existing two gas turbines and the two auxiliary boilers, to remove the carbon dioxide (CO₂) for subsequent compression and storage. At full power plant load, the PCC plants could capture up to 3.3 million tonnes of CO₂ per year from the flue gases from the Installation.

A substantial variation to the Environmental Permit for the Installation is required to incorporate the PCC plants as a new Schedule 1 activity.

The VPI PCC plants comprise part of the wider Humber Zero Project (HZP), which consists of two Proposed Developments to install PCC plants and associated facilities located at the VPI Immingham CHP Power Plant and the adjacent Phillips 66's Humber Refinery.

The CO₂ transmission network that the developments within the HZP will connect into for transport to storage sites under the North Sea is currently under development by others. There are two potential Transmission and Storage (T&S) networks that the VPI PCC plants could be connected to: either the Viking CCS CO₂ gathering network (promoted by Harbour Energy) or the East Coast Cluster Humber Low Carbon Pipelines, also known as Zero Carbon Humber (promoted by National Grid). Both pipeline networks will run close to the Installation and the decision as to which network will be connected to initially will be made following Government funding announcements and pipeline availability. It is likely that access to both transportation networks would be available in the long-term.

The PCC plants will be located to the south of the existing Installation Site Boundary on vacant land that will be leased from the adjacent Phillips 66 Humber Refinery site. The extended Installation Site Boundary is shown in Figure 3 and an indicative layout of the PCC plant area is shown in Figure 4 (Appendix A).

The PCC plants will use an amine-based solvent to strip CO₂ from the flue gas from the existing Gas Turbine (GT) 1 and GT2, as well as the two auxiliary boilers, within packed absorber columns, via a weak acid-base reaction. The CO₂-depleted flue gas will then pass through emissions abatement equipment (a water wash and mist eliminator) prior to its release to atmosphere via dedicated stacks on top of the PCC plant absorber towers. These will comprise new Emission Points to air (A6 and A7).

The CO₂ will be removed from the CO₂-rich solvent in a CO₂ stripper (or regeneration column) by heat, using steam provided by the VPI CHP Power Plant, enabling the lean amine-solvent to be recycled back into the absorption process for reuse.

The CO₂ gas will undergo low-pressure (LP) compression, with dehydration and de-oxygenation also carried out. It will then undergo high-pressure (HP) compression on-site, to dense phase before being exported off-site to the third-party T&S operator for transport to permanent underground storage.

Over time, the amine-based solvent can accumulate impurities, and these will be removed via a solvent thermal reclaiming process which will be carried out continuously within the PCC plant area. A slip stream of solvent from the absorbers will be fed to the thermal reclaimer unit, and will be heat treated to remove any solvent degradation products to prevent their build up.

The capture of CO₂ using amine-based solvents is a proven technology, used for many years in oil refineries and gas processing plants. More recently, it has been employed at a number of power stations worldwide, although its use in the UK is still very much in the early phase of development and deployment.

The design and operation of the PCC plants is intended to meet the indicative requirements of Best Available Techniques (BAT) as defined for Carbon Capture and Storage (CCS), as summarised in this Supporting Document and described in full in Appendix D.

The main PCC stack emissions will comprise residual pollutants from the GTs and auxiliary boilers, including oxides of nitrogen (NO_x), carbon monoxide (CO), sulphur dioxide (SO₂), particulates (SO₂ and particulates are present due to the potential use of Refinery Off Gas, as a fuel in the auxiliary boilers and will only be present in trace amounts) and some residual CO₂; the PCC plants will be designed to optimise CO₂ capture and to achieve approximately 95% capture rates during normal operation. There may also be trace pollutants within the flue gas, including trace levels of amine from the solvent and amine break-down products from within the carbon capture process. These amine emissions will be monitored and minimised using a water wash section and mist eliminator at the top of the PCC plant absorbers prior to final release to air of the flue gas.

The GTs and auxiliary boilers are classified as Large Combustion Plant (LCP) under the Industrial Emissions Directive (IED) and therefore must meet the BAT-Achievable Emission Levels (BAT-AELs) detailed in the associated BAT Conclusions document. BAT-AELs for CCGTs and boilers differ, due to the different technologies resulting in different emission concentrations, and also the reference conditions used to calculate released emission concentrations differ. As each PCC plant will take the flue gases from one GT and one aux boiler it will not be possible to demonstrate ongoing compliance with the relevant LCP BAT-AELs through pollutant monitoring at the PCC plant absorber stacks. As such, it is proposed that the combustion emissions from the individual GTs and auxiliary boilers will be monitored prior to being combined in the PCC plants. Additional monitoring will be undertaken at the PCC stacks for any species that result from operation of the PCC plants.

Through an air quality impact assessment, undertaken in accordance with Environment Agency (EA) guidance, appropriate stack heights and amine and their degradation products emission levels have been determined for the PCC plant stacks, in order to minimise impacts on air quality receptors from the main pollutants. The assessment includes dispersion modelling of maximum emission parameters and prediction of maximum process contributions, to determine the worst-case predicted environmental concentrations which were then compared with relevant air quality standards or Environmental Assessment Levels.

The assessment also includes consideration of the potential impacts associated with breakdown products of an amine-based solvent, from both within the process ('direct' emissions) and as a result of chemical interactions within the atmosphere ('indirect' emissions) which is beyond the normal scope of the EA's risk assessment method. The impact assessment for the operation of the PCC plant is presented in Appendix F.

In addition to the main PCC plant emission points on the absorbers, there will be a CO₂ vent on the CO₂ compression plant for use during start-up and shut-down, and in the event of abnormal operation. An assessment of CO₂ venting has been carried out and is presented in Appendix H. Any venting required for the off-site T&S Network pipeline will be provided by the T&S Network provider and therefore will not be associated with this Installation.

Uncontaminated surface water from the PCC plant area will be routed via an oily water separator to a new balancing/ holding pond prior to being discharged via a new Emission Point to water, W2, to South Killingholme Drain.

Any potentially contaminated surface water will be collected in sumps and sent to the Drain Drum. Process drains from compression and conditioning systems and drains provided for the routine draining of equipment and pipework for maintenance operations will also be sent to the Drain Drum. All waters collected in the drain drum will be tested to ensure they are suitable to send to the oily water separator and new balancing pond, and if not, they will be disposed of offsite by a licensed waste contractor.

As far as practical, drained fluid from amine processing systems will be retained and returned to the appropriate system for reuse or, if this is not possible, it will be sent off-site for disposal by a third-party licensed waste contractor.

Wastes generated by the PCC plants, such as waste from the thermal reclaimer, will be collected and stored onsite prior to disposal off site via a licensed waste contractor. Other than thermal reclaimer

waste, wastes from the PCC plants are expected to be minimal, and will be appropriately disposed of via a licensed 3rd party in line with current Installation procedures.

A Noise Impact Assessment has been carried out to support the Permit application and is provided in Appendix I. The assessment looked at the baseline noise levels at Noise Sensitive Receptors without the operation of the existing Installation, noise levels with the operation of the existing Installation and then noise levels of the future operation of the existing operations with the additional PCC plants.

The Installation is operated in line with the existing ISO14001 accredited Environmental Management System (EMS), which will be updated to include additional operating procedures to manage the various aspects of the operation of the PCC plants, including but not limited to emissions monitoring, accident management, waste minimisation and management, and infrastructure maintenance.

2. Introduction

VPI Immingham LLP ('VPI') operates the Immingham Combined Heat and Power (CHP) Power Plant (the 'Installation') in Immingham, North Lincolnshire, under the existing Environmental Permit reference EPR/BJ8022IZ. The Installation's location and Site Boundary are provided in Figures 1 and 2 (Appendix A).

VPI intend to retrofit two Post-Combustion Carbon Capture (PCC) plants treating the flue gas emitted from the Installation's existing two gas turbines and two auxiliary boilers to remove the carbon dioxide (CO₂) for subsequent compression and storage. At full load of the generating station, the PCC plants could capture up to 3.3 million tonnes of CO₂ per year from the flue gases from the Installation.

This document presents the supporting information for a substantial Environmental Permit variation application made under the Environmental Permitting (England and Wales) Regulations 2016 (as amended) ('the EP Regulations'), and is submitted on behalf of VPI to vary the existing Environmental Permit to incorporate the PCC plants as a new Schedule 1 activity.

The VPI PCC plants comprise part of the wider Humber Zero Project (HZP) which consists of two Proposed Developments to install PCC plants and associated facilities located at VPI's Immingham CHP Power Plant and at the adjacent Phillips 66's Humber Refinery.

The Humber is the largest industrial cluster in the UK in terms of existing CO₂ emissions, emitting approximately 20 million tonnes of CO₂ per year. The PCC plants will remove approximately 95% of CO₂ from the treated emissions from the GTs and Aux Boilers during normal operation, representing a 16% reduction in the overall emissions from the Humber industrial cluster, thereby contributing towards the UK Government's legally binding target to reach net zero by 2050.

The CO₂ transmission network that the developments within the HZP will connect into for transport to storage sites under the North Sea is currently under development by others. There are two potential Transmission and Storage (T&S) networks that the VPI PCC plants could be connected to: either the Viking CCS CO₂ gathering network (promoted by Harbour Energy) or the East Coast Cluster Humber Low Carbon Pipelines, also known as Zero Carbon Humber (promoted by National Grid). Both pipeline networks will run close to the Installation and the decision as to which network will be connected to initially will be made following Government funding announcements. It is likely that access to both transportation networks would be available in the long-term.

A Town and Country Planning application (TCPA) for the Proposed Development of the VPI PCC plant has been made and is currently being determined by North Lincolnshire Council. A copy of the Environmental Statement (ES) prepared to support the Town and Country Planning application is included in Appendix B.

Due to the critical project timelines, long Environment Agency (EA) permit determination periods and the need to demonstrate that a permit is in place to enable the project to reach Final Investment Decision, this Environmental Permit variation is being made before detailed project design has been completed. As such, it is recognised, that further information may need to be provided to the EA following completion of the early detailed design process, in order to reflect design changes that may have occurred after this variation application has been submitted. Where possible, conservative or worst-case assumptions have been used in this variation application.

The PCC plant area will be situated to the south of the existing Installation Site Boundary on vacant land that will be leased from the adjacent Phillips 66 Humber Refinery site. The extended Installation Site Boundary is shown in Figure 3 (Appendix A).

2.1 Background

The VPI Immingham CHP Power Plant was built in 2004, on land that had primarily been used for agricultural use or consisted of marshland. The Installation was commissioned with a generating capacity of 730MW to supply steam and electricity to the adjacent Humber and Lindsey Oil Refineries. Electricity is also supplied to the National Grid. The original Installation comprised the existing Combined Cycle Gas Turbines (CCGT) GT1 and GT2 and two auxiliary boilers (Aux Boiler 1 and Aux Boiler 2).

The Installation expanded to have a generating capacity of 1,180MW in 2009 when a 285MW gas turbine and 200MW heat recovery steam generator (HRSG) was added to the operations (GT3).

The area for the PCC plants and high-pressure CO₂ booster compression station is to the south of the existing Installation Site Boundary and comprises an area of approximately 8.8ha of grassland with an open ditch running through the centre, areas of hardstanding and some existing below ground utilities. The area was previously used for laydown during the construction of the existing Installation.

The plant and associated facilities for capturing CO₂ from GT1 and GT2 and the two Aux Boilers will comprise two PCC plant units, each with a dedicated train of CO₂ compression, oxygen removal and dehydration to achieve a pure CO₂ stream at approximately 135 barg required for export to the CO₂ T&S network. The PCC plants will be designed for approximately 95% CO₂ capture during normal operation.

GT3 does not form part of the PCC plant works, as options to convert it to hydrogen firing in the future are being considered as part of the wider Humber Zero project. As such, no further consideration of GT3 has therefore been made as part of this Environmental Permit variation, and any future conversion to hydrogen firing would be subject to a separate Environmental Permit variation.

2.2 Proposed Operations

2.2.1 Listed Activities under Schedule 1 of the EP Regulations

Schedule 1 Table S1.1 of the Installation's existing Environmental Permit comprises scheduled activity AR1 (covering all combustion activities) and directly associated activities AR2 – AR5.

The EP Regulations include a listed activity in Section 6.10 for the "*Capture of carbon dioxide streams from an installation for the purposes of geological storage pursuant to Directive 2009/31/EC of the European Parliament and of the Council on geological storage of carbon dioxide*". This variation application will therefore add the Section 6.10 listed activity of Carbon Capture and Storage together with a number of directly associated activities (DAA) to the Installation's Environmental Permit. It is therefore proposed to vary Schedule 1 Table S1.1 of the existing Environmental Permit as shown in Table 2.1.

Table 2.1: Schedule 1 Listed Activities

Activity Ref	Activity listed in Schedule 1 of the EP Regulations	Description of Specified Activity	Limits of Specified Activity	Changes Detailed in this Variation
AR1	Section 1.1 Part A(1)(a): Burning of any fuel in an appliance with a rated thermal input of 50MW or more.	<p>Production of electrical power and steam in a Combined Heat and Power (CHP) plant comprising the following LCPs:</p> <p>LCP188</p> <ul style="list-style-type: none"> Gas turbine (GT1) and Heat Recovery Steam Generator (HRSG1), CCGT mode; GT1: 730MWth, natural gas fired; HRSG1: 111 MWth, natural gas supplementary firing. Gas turbine (GT2) and Heat Recovery Steam Generator (HRSG2), CCGT mode, GT2: 743 MWth, natural gas fired; HRSG2: 111 MWth, natural gas supplementary firing. Two auxiliary boilers AB1 & AB2 for production of steam, 290MWth each, fired by natural gas and/or refinery off- 	From receipt of natural gas, ROG or gas oil to discharge of exhaust gases and wastes, and the generation of electricity and steam for export.	Addition of PCC plant to LCP188. No change to LCP415.

Activity Ref	Activity listed in Schedule 1 of the EP Regulations	Description of Specified Activity	Limits of Specified Activity	Changes Detailed in this Variation
		gas (ROG) or gas oil as stand-by fuel. LCP415 <ul style="list-style-type: none"> Gas turbine (GT3) and Heat Recovery Steam Generator (HRSG3), CCGT mode, GT3: 751 MWth, natural gas-fired; HRSG3: 193 MWth, natural gas and/or ROG supplementary firing. 		
AR2	Section 6.10 Part A(1): Carbon Capture and Storage.	Operation of post combustion Carbon Capture plant retrofitted to GT1, GT2, and the auxiliary boilers (AB1 and AB2)	From receipt of exhaust gas from HRSG1 and HRSG2 and AB1 and AB2 into the PCC plants to the treatment of the gas prior to export or release to atmosphere.	New activity to be added to the permit. The treatment of exhaust gas from HRSG1, HRSG2, AB1 and AB2 into the PCC plants using an amine-based solvent to extract the CO ₂ , followed by compression and dehydration of the treated CO ₂ for off-site transfer and storage; and release of CO ₂ -abated flue gas to atmosphere.
Directly Associated Activity				
AR3	Directly Associated Activity	Processing of raw water to produce water of quality fit for use in LCP188 cooling tower system and process waters from the refineries being demineralised for demineralised water production.	Treatment of water supplied from the adjacent oil refinery for use in the LCP.	New activity reference number due to additional listed activity. No other changes.
AR4	Directly Associated Activity	Oil storage	From receipt of raw materials to dispatch for use.	New activity reference due to additional listed activity. No other changes.
AR5	Directly Associated Activity	Surface water drainage	Handling and storage of site drainage until discharge to the site surface water system, and discharge to the South Killingholme Drain.	New activity reference due to additional listed activity. Additional PCC plant area drainage.
AR6	Directly Associated Activity	Water treatment	From receipt of raw materials to dispatch to chemical effluent and waste water system.	New activity reference due to additional listed activity. No other changes.
AR7	Directly Associated Activity	Raw materials handling and storage – receipt, storage and	From receipt of raw materials to their point of use.	New activity. The PCC plants will require storage

Activity Ref	Activity listed in Schedule 1 of the EP Regulations	Description of Specified Activity	Limits of Specified Activity	Changes Detailed in this Variation
		handling of carbon capture solvent		of an amine-based solvent in dedicated above ground tanks, in addition to small quantities of chemicals for use for maintenance works.
AR8	Directly Associated Activity	Solvent reclaiming	From receipt of solvent in the PCC plant thermal reclaimer to discharge to storage	New activity. The removal of impurities in the amine-based solvent by thermal reclaiming using steam distillation, for re-use in the PCC plants.

2.3 Environmental Setting

The topography of the area surrounding the Installation comprises a low-lying estuarine landscape consisting of extensive stretches of intertidal habitats containing mudflats, saltmarsh, coastal dunes and wetland adjacent to the Humber Estuary.

The surrounding land-use is dominated by the large heavy industrial areas (including the Humber and Lindsey Oil Refineries and the Humber Ports site) around the villages of North and South Killingholme and the town of Immingham. This industrial land-use is mixed with interspersed pockets of flat open farmland, woodland and natural coastal habitats. There is more sporadic development to the north of the Installation as the land-use becomes more rural with more isolated development.

The Humber Estuary Special Area of Conservation (SAC), Special Protection Area (SPA), Site of Special Scientific Interest (SSSI) and Ramsar is approximately 1.6km east of the Installation and there are six Local Wildlife Sites (LWS) within 2km of the Installation.

The location of the Installation is shown in Figure 1 (Appendix A).

Further detailed on the environmental setting and local receptors is presented in Section 7.

3. Site Condition Report

The PCC plants are to be developed on vacant land to the south of the existing Installation Site Boundary, covering an area of approximately 8.8 ha. As such, the PCC plant area will need to be added to the Installation Site Boundary as part of this Environmental Permit variation. The existing Installation Site Boundary is shown in Figure 2, with the revised Installation Site Boundary shown in Figure 3 (Appendix A).

An assessment of the current site conditions of the additional land to be included in the revised Installation Site Boundary has been undertaken to add to the existing Installation's baseline. The Site Condition Report for the PCC plant area, including a baseline, is presented in Appendix C. A Conceptual Site Model is presented in the ES provided in Appendix B of this document (see ES Volume II, Appendix 10A).

The area for the PCC plants is currently bisected by a drain maintained by North-East Lindsey Internal Drainage Board (IDB). This will be redirected around the perimeter of the PCC plant area prior to the construction of the PCC plants.

With the exception of some small areas, the PCC plant area lies within Flood Zone 3 and is therefore classified as having a 'high risk' of flooding from fluvial or tidal sources.

The environmental sensitivity of the PCC plant area is considered to be as follows:

- Groundwater - Low to High sensitivity - The underlying Burnham Chalk Formation bedrock deposit is classified as a Principal aquifer. The underlying superficial deposits consist of Sedimentary superficial deposits (Devensian till), which is classified as a Secondary (Undifferentiated) Aquifer.
- Surface water – High sensitivity – The Humber Estuary is located approximately 1.6km east of the Installation, and is a statutory designated site.
- Land use – Low sensitivity – the Installation is surrounded by industrial and agricultural land and no significant land uses have been identified.

4. Operating Techniques

4.1 Technical Standards

The Installation will continue to operate in accordance with the conditions of the existing Environmental Permit and also applicable EA Sector Guidance, in particular to the Large Combustion Plant (LCP) sector guidance.

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

The PCC plants will be covered as a Section 6.10 A(1)(a) - *Capture of carbon dioxide streams from an installation for the purposes of geological storage pursuant to Directive 2009/31/EC of the European Parliament and of the Council on the geological storage of carbon dioxide* listed activity and therefore will follow the sector guidance for Post-combustion Carbon Capture:

- Post-combustion Carbon Dioxide Capture: Best Available Techniques (BAT) Guidance (PCC BAT)¹, and accompanying 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 (BAT Review)².

It should be noted that the EA Guidance does not have the same legal status as BRefs published under the IED, and indeed the webpage states that *“Except where stated, this BAT guidance is not a regulatory requirement but identifies important environmental issues to address and best practice”*. However, a review of the PCC plants to be installed at the Installation has been carried out against this BAT Guidance and is provided in Appendix D.

The PCC plant will be operated in accordance with the existing management system for the Immingham CHP Power Plant, which will be amended as required to include the proposed operations of the PCC plants prior to the commencement of their operation. The existing management system is compliant with the EA guidance - ‘Develop a management system: Environmental Permits’³.

4.2 Process Description

4.2.1 Overview

There will be no change to the existing operation of GT1, GT2, Aux Boiler 1 and Aux Boiler 2 from that described in the original Permit application for the Installation as a result of the installation of the PCC plants, and therefore no discussion of the upstream combustion process is included in this variation application.

There will be two PCC plants, with each one being designed with a capacity to process 100% of the flue gas from one GT plus 60% of the flue gas from one Aux Boiler. It will be possible to process 100% of the flue gas from one Aux Boiler when the GT is at part load. The PCC plants will tie into the existing flue ducting from the GTs and Aux Boilers, and routing dampers will be installed to enable the flue gases to be diverted from the existing stacks to the new PCC plants. GT1 flue gas will only be directed to PCC plant 1, whilst GT2 flue gas will only be directed to PCC plant 2. The two Aux Boilers however, will be manifolded such that either Aux Boiler flue gas source can be directed to either PCC plant.

Each PCC plant will contain a licensed solvent-based unit designed to selectively remove the CO₂ from the flue gas feed and vent treated flue gas to atmosphere. VPI have selected a proprietary amine-based carbon capture processes, utilising the latest in amine solvents, Cansolv DC-103. Shell is a leading provider of CO₂ capture technologies, and their technology was selected by VPI following an extensive assessment which found it to be the best technology for the GT and aux boiler flue gases in terms of capture efficiency, energy efficiency and environmental performance. Shell also has significant

¹ Available at: [Post-combustion carbon dioxide capture: best available techniques \(BAT\) - GOV.UK \(www.gov.uk\)](https://www.gov.uk/guidance/post-combustion-carbon-dioxide-capture-best-available-techniques-bat)

² Available at: [Best Available Technology \(BAT\) information for CCS | UKCCSRC](https://www.gov.uk/guidance/best-available-technology-bat-information-for-ccs)

³ Develop a management system: Environmental Permits, EA, Published: February 2016, Last Updated on: 04th August 2021, accessed at <https://www.gov.uk/guidance/develop-a-management-system-environmental-permits> on 17th August 2022

operational experience of their technology and solvents, which have been commercially deployed since 2012. The Shell Cansolv system was also used in the first large scale capture of CO₂ from a coal-fired power station (Boundary Dam) commencing in 2014 and still operational today.

Proprietary solvents, such as Cansolv DC-103 are considered to offer significant benefit over the mature single solvent option of Monoethanolamine, due to its lower volatility leading to lower emissions and solvent degradation rates, improved capture rates and better energy efficiencies.

On entering the PCC plant area, the exhaust gases from GT1, GT2 and the Aux Boilers will first pass through a pre-treatment stage of quenching via a direct contact cooler (DCC) before passing to the main PCC plants for CO₂ abatement. Once cooled in the DCC, the exhaust gas will pass to the main PCC plant, where it will travel up through a counter-flow, packed absorption column against a falling solvent, into which the majority of the CO₂ content within the flue gas will be absorbed. The treated flue gases (CO₂-abated flue gas) will then pass through solvent retention and air emissions mitigation stages and will subsequently be released to atmosphere via stacks located on top of the absorption columns.

The CO₂-rich solvent will leave the bottom of the absorption column and be routed to the top of the CO₂ stripper, via a crossflow heat-exchanger, where it will pass down a packed column, 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 plants 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 plants will deliver up to 3.3 million tonnes per year of abated CO₂ emissions via the Post-combustion Carbon Capture retrofit of the existing GT1, GT2 and two Aux Boilers.

The extent of the PCC plant area within the extended Installation Site Boundary is shown in Figure 3 (Appendix A). The proposed layout of the PCC plant area is illustrated in Figure 4 (Appendix A). The PCC plants will include the following components:

- ducting to connect the existing Installation to the PCC plants;
- two trains of PCC plants, each with associated booster fan, DCC, absorber column, stack, CO₂ stripper column, and air-cooled heat exchangers;
- two (one on each train) integrated CO₂ compression, oxygen removal and dehydration facilities;
- electrical sub-stations;
- a shared chemicals store for the two PCC plants, including off-loading facilities and storage tanks;
- a shared thermal solvent reclaimer unit;
- CO₂ metering and pipelines connecting the PCC plants to the compression facilities and the CO₂ T&S network interface; and
- surface water drainage system.

A process flow diagram for a PCC plant is provided in Figure 5 (Appendix A).

The PCC plants will be designed to operate 24 hours a day, 7 days a week as per the existing Installation.

4.2.2 Flue Gas Pre-Treatment

Each flue gas source will have a dedicated booster fan or blower to ensure that there is sufficient pressure to drive the flue gas through the ducting to the relevant DCC and then on to the PCC plant. In the event of failure of a booster fan, flue gas will be diverted back to the existing Emission Points (A1 – A4).

Following the booster fans, the flue gases from GT1, GT2 and the Aux Boilers will require cooling prior to entering the PCC plants, and this will be carried out in the DCCs. In each PCC plant train, the DCC will saturate and cool the flue gas prior to the CO₂ Absorber Column, to ensure optimum conditions for CO₂ absorption and to prevent excessive water evaporation from the solvent solution occurring within

the absorber. The flue gas will be cooled to the required temperature for the carbon capture process by direct contact with recirculating water within the DCC. The recirculating water will be cooled against air in the DCC Water Cooler.

When the Aux Boilers are fired on Refinery Off-gas, caustic will be dosed into the recirculating water in the DCC to maintain an appropriate pH to reduce the concentration of oxides of sulphur (SO_x) in the flue gas. This will reduce the potential for solvent degradation, which can result when acid gases such as SO_x is present in the PCC process.

Clean water condensed from the flue gas in the bottom section of the DCC will be sent to existing Raw Water Tank and subsequent treatment in the demin plant for reuse on site. In the event the Raw Water Tank is full, the condensed water will be sent to a new holding pond in the PCC plant area from where it will be discharged through a new Emission Point W2, to South Killingholme Drain.

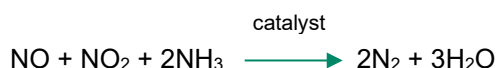
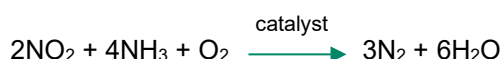
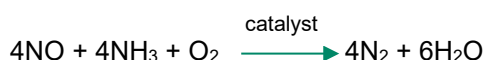
It is not considered necessary to install Selective Catalytic Reduction (SCR) on the GTs or Aux Boilers to reduce the NO_x emissions in the flue gases going into the PCC plants. It is the presence of NO₂ specifically in the flue gas NO_x (comprising both nitric oxide NO and nitrogen dioxide NO₂) that has the potential to lead to the degradation of the solvent and generate nitrosamines. This is recognised in the BAT Review, which references that it is NO₂ specifically that reacts to form nitric acid and subsequent heat stable salts and nitrosamines if secondary amines are present.

Pilot plant and operating plant results from the Cansolv DC-103 solvent has confirmed that the formation of nitrosamines results exclusively from reaction with NO₂, as (physical) absorption in the solvent of NO is very low and it does not react with the amine.

The BAT Review states that it has been suggested that NO₂ concentrations should be restricted to 27mg/Nm³ to avoid nitrosamine formation. Although this is specifically mentioned for Energy from Waste applications, it is considered to be relevant to all combustion activities.

NO_x emissions from combustion sources are dominated by NO, with emissions from combustion sources typically in the ratio of NO to NO₂ of 9:1. Based on the existing ELV and typical combustion ratios, the flue gas from the Installation's GTs would have NO₂ concentrations of 4 – 5mg/Nm³, whereas the Aux Boilers NO₂ flue gas concentrations would be slightly higher at 8 – 10mg/Nm³. Recent monitoring to characterise the flue gas more accurately, however, has indicated that the NO₂ concentrations, particularly for the Aux Boiler flue gases are lower. That said, using these estimated values as a worst case, given that the Aux Boilers will only provide approximately 25% of the flue gas going into the PCC plant, the overall NO₂ concentration would be in the region of 6 – 8mg/Nm³. As such, concentrations of NO₂ specifically in the flue gas going to the PCC plants will be well below the 27mg/Nm³ referenced in the BAT Review to minimise nitrosamine formation.

The main SCR reactions are:



The reaction equations show that one mole of NH₃ is required to remove one mole of NO and two moles of NH₃ are required to remove one mole of NO₂. The reaction with NO is the predominant reaction because >90% of NO_x in flue gas from combustion units is NO. A reduction in NO_x concentration from 50mg/Nm³ to 30mg/Nm³ for example, may only result in a reduction in NO₂ concentrations of 2mg/Nm³. Therefore, due to the low NO₂ concentration in the GT and aux boiler flue gas, it is considered that the use of an SCR would only marginally reduce the NO₂ present and would have very limited impact on nitrosamine formation in the solvent.

Even if a substantial reduction in NO₂ inlet concentration could be achieved, it would not necessarily result in reduction in nitrosamine emissions as these emissions are formed through a complex function of solvent chemistry (nitrosamine stability, fraction in free base form) and water-wash efficiency.

There would also be cross-media effects associated with the installation of SCR. For example, there would be additional ammonia emissions to air due to ammonia slip, and this would have potential additional nitrogen deposition impacts at ecological receptors in the vicinity of the Installation, given that the deposition velocity of ammonia is considerably higher than that of NO_x. Although these emissions could be reduced through an acid wash, this would result in an acidic wastewater stream that would require treatment and generate both waste water and solids requiring disposal. In addition, it would also result in ammonia within the DCC water, which could preclude its reuse on site unless additional treatment was applied.

There are also technology challenges that would need to be overcome to install SCR at the Installation. Normally the SCR catalyst is installed in the HRSG or boiler, between the heaters at an appropriate place with optimum temperatures for the SCR. However, there is no space in the existing HRSGs and Aux Boilers to retrofit the SCR catalyst to be located in the high temperature zone upstream of the economisers. Therefore, the flue gas could only be treated downstream of the economisers, in the new duct between the booster fan and the DCC, i.e. a tail-end system. Such a system will have higher capital (CAPEX) and operating (OPEX) costs than the other typical SCR systems because of the additional equipment and operational costs associated with flue gas reheating and heat recovery. The flue gas temperature from the GT and Aux Boilers economisers are 110°C and 180°C respectively. These temperatures are outside the acceptable range for SCR and therefore reheat of the flue gas to over 300°C would be required prior to the SCR, which increases the SCR operational cost and would reduce the energy efficiency of the PCC plant. The requirement to reheat the flue gas for the SCR, would then result in additional downstream cooling duty of the flue gas in the Direct Contact Cooler (DCC) to ensure the flue gas was the optimum temperature for the PCC plant.

The estimated CAPEX of installing SCR to treat the flue gases from the GTs and aux boilers is £90 million, and the estimated OPEX is £5.4 million. The OPEX of the additional power required to reheat and then cool the flue gases is £4 million alone.

As such, it is considered that the installation of SCR would add significant technical complexity, cost and cross-media effects to the project and would provide very limited reduction, if any, in the direct emission of nitrosamines. The proposed emission concentrations of directly released nitrosamines from the PCC plants are very small, as shown in Section 5.1.1. In addition, the impacts of the direct emission are demonstrated in the Air Quality Assessment (Appendix F) to not lead to exceedances of the relevant Environmental Assessment Level (EAL). As such, it is not considered necessary to retrofit SCR and its use is not considered to represent BAT for this installation.

4.2.3 Post-combustion Carbon Capture Process

The PCC plants are amine-based solvent, post-combustion carbon capture plants that will be designed to capture approximately 95% of the CO₂ from the pre-treated flue gas received from the DCC. At full load of the generating station, this could equate to capture of around 3.3 million tonnes of CO₂ per year from the flue gases from GT1, GT2 and the Aux Boilers.

The CO₂ abated flue gas will be vented via new emission points directly on the top of the CO₂ Absorber Columns (Emission Points A6 and A7), while the captured CO₂ will be sent for compression and conditioning prior to export to the CO₂ T&S network.

Each CO₂ PCC plant comprises the following major components:

- a CO₂ Absorber column, including a water wash section;
- CO₂ Stripper; and
- solvent filtration unit (incorporating Solvent Drain System).

The two PCC plants will share the following common facilities:

- Thermal Reclaimer unit; and
- solvent and chemical storage facilities.

4.2.3.1 Carbon Dioxide Absorption

The cooled CO₂-rich flue gas from the DCC will enter at the bottom of the PCC plant Absorber Column, where it will contact the lean amine solvent that will remove the CO₂ from the flue gas. The CO₂-rich flue gas will pass up through the Absorber Column, with the lean solvent flowing down, counter-current, through the multi-level packed-bed Absorber, to ensure good contact efficiency is maintained throughout the Absorber Column. The CO₂ will become chemically bound by the amine solvent as the alkaline nature of the solvent will mean that it selectively absorbs acidic gases such as CO₂.

The equilibrium limit for the reaction will be reached at the top of the Absorber Column where the leanest lean solvent contacts the exhaust gas with minimum CO₂ concentration. The overall carbon capture efficiency is given by the difference in exhaust gas inlet and outlet CO₂ concentrations.

The gas entering the absorption section of the Absorber Column will have sufficient pressure to overcome the pressure drop in the tower packing before being discharged to atmosphere due to the booster fan.

Typical operating temperatures in the Absorber Column range from 40°C to 80°C, depending on the process design parameters such as the compositions of the solvent and exhaust gas, as well as the presence of any intercooling arrangement in the Absorber Column. The reaction between the solvent and the CO₂ is exothermic, as such the flue gas temperature is increased through the main packed bed of the Absorber Column.

The treated flue gas leaving the top of the Absorber Column will pass through a water wash section and a mist eliminator, before being released to the atmosphere.

4.2.3.2 Wash Water Section

The Absorber Columns will have a water wash section at the top, which will remove entrained solvent in the CO₂-lean flue gas prior to its release, in order to minimise solvent carry-over into the waste gases discharged from the PCC plant. The water used in the water-wash section is continuously recycled and cooled in the Water-Wash Cooler. As such, water is condensed from the flue gas in the water wash section, and any excess water is drained to the solvent loop to prevent solvent build-up in the water wash section and to minimise both solvent and water consumption.

The proportion of water in the recirculating amine solvent needs to be managed to ensure that this does not accumulate due to condensation of the flue gas. The amine solvent will be routinely sampled and analysed to determine whether excess water requires purging from the system. Purged diluted amine will be retained and utilised as amine dilution water when fresh amine is required.

No acid wash is proposed for the Absorber Columns, as it is considered that the amine emissions can be controlled to low concentrations without requiring further treatment, as shown in Section 5.1.1.

A mist eliminator will also be located at the top of water wash section to prevent the entrainment of droplets into the waste gases before they are released to air from the top of the Absorber Columns via dedicated stacks (new Emission Points A6 and A7).

The Absorber Columns will be approximately 60m high packed towers utilising structured packing to minimise gas path pressure drop. The packed column design meets indicative BAT requirements for maximising absorption efficiency.

4.2.4 CO₂ Stripping and Solvent Regeneration

The CO₂-rich solvent, collected in the sump of the CO₂ Absorber Columns, will be pumped to the CO₂ Strippers for solvent regeneration and CO₂ recovery via the rich solvent heat exchangers, which will warm the CO₂-rich solvent. The CO₂ Strippers will consist of a stripping section with a collector tray below the packing and a reflux section on top of the column to maximise the solvent-CO₂ separation. The rich amine will enter the CO₂ Strippers on top of the stripping section of the column and the CO₂ will be removed from the amine by steam rising up through the column which breaks the CO₂-amine bond.

The lean solvent will then accumulate in the bottom tray of the column and be routed to the CO₂ Stripper reboiler. The solution will be heated by low pressure (LP) steam and transferred back to the bottom section of the CO₂ Strippers where the flashed vapours will be separated from the liquid and the vapour will re-enter the stripping section to strip out any remaining CO₂ from the solvent.

The gas from the stripping section will pass through the reflux section of the CO₂ Strippers, and will be routed to the reflux condenser. The residual steam is condensed, and liquid is separated from the gas in the reflux drum. The bulk of the liquid is returned to the top of the reflux section of the CO₂ Absorbers.

The hot lean solvent from the CO₂ Strippers will be passed through a heat exchanger to be cooled before the solvent re-enters the Absorber Columns for reuse. The removed CO₂ will be routed from the top of the CO₂ Stripper columns where a portion of the vapour will be condensed by recycled reflux to enrich the overhead CO₂ gas stream. The CO₂ Stripper overhead gas will be partially condensed by cooling in the CO₂ Stripper condenser. The partially condensed two phase mixture will flow under gravity to the CO₂ Stripper reflux drum where the two phases will separate. The reflux water will be collected and returned via the CO₂ Stripper reflux pumps to the CO₂ Stripper rectification section. In addition, a connection is also provided at the reflux pump discharge to provide reflux make-up to the CO₂ Absorber wash water section if required.

The CO₂ will flow from the CO₂ Stripper reflux drum to the CO₂ Compressors.

4.2.5 Solvent Management and Reclaiming

The recirculating solvent can accumulate insoluble contaminants entrained within the flue gas and therefore the effective management of the solvent is fundamental to the maximisation of efficiency of the PCC plants. In addition, oxidative degradation, where amines react with oxygen, NO₂ or SO₂ to form corrosion products including ammonia, can occur at temperatures between 40 - 55°C and particularly in the presence of particulate impurities. As previously discussed in Section 4.2.2, it is considered that NO₂ is already at sufficiently low levels to minimise this as far as possible. The flue gas pre-treatment proposed to reduce SO₂ in the flue gas entering the PCC plant when the aux boilers are firing on ROG will also help to minimise oxidative degradation.

Thermal degradation of the solvent will be minimised by ensuring the temperature of the regeneration process is optimised for the amine-based solvent to be used within the PCC plants. The selection of appropriate materials of construction is also necessary to minimise this risk.

The use of solvent management techniques specific to the solvent will minimise waste generation and optimum capture performance in accordance with indicative BAT for PCC plant. However, despite good solvent management controls, the lean solvent may pick up dust or other insoluble contaminants as it flows through the PCC plant. To prevent the build-up of such contaminants, a filtration system comprising a mechanical filter and a carbon bed filter will be in place to process a slip stream of the lean solvent. Once filtered, the majority of solvent will return to the PCC plant for reuse, however a portion will be sent to the Thermal Reclaimer to remove solvent degradation products, to prevent these from building up within the process.

Solvent reclaiming will be undertaken as a continuous process. A solvent slip stream from the filtration unit (approximately 0.1% of the PCC plant inventory) will be dosed with caustic to ensure the correct pH is achieved and then fed to a preheater, where it will be heated by medium pressure (MP) steam prior to entering the Thermal Reclaimer.

The Thermal Reclaimer will be a single column with a reboiler heated by MP steam at the column base. The column will operate at vacuum and will separate out of most of the water and reclaimer lean solvent (overheads) from the degradation products (bottoms). Steam sparging will be available at the base of the Thermal Reclaimer column to reduce viscosity and aid solvent reclamation.

The overheads will be partially condensed in the Thermal Reclaimer condenser and the resultant two-phase mixture will then be separated in the Thermal Reclaimer reflux drum. The vapour will then be sent to the Thermal Reclaimer vacuum system. The degradation products build up in the Thermal Reclaimer until they reach a specified level when they will be collected at the bottom of the Thermal Reclaimer column and pumped to the Degraded Solvent Drum for storage, prior to disposal offsite via a licenced waste contractor.

The chosen technology for the removal of degradation products is thermal reclamation and it is considered that this represents BAT as thermal reclamation is a mature technology, capable of removing non-ionic heavier molecular weight degradation products, including metals and polymeric compounds all formed via thermal degradation. In applications with low flue gas contamination, such as from the VPI CHP plant, the amounts of ionic degradation products (low molecular weight acids) and heat stable inorganic salts is considered to be low, and therefore the use of ion-exchange resins is not considered

appropriate. These species are also removed via thermal reclamation and therefore it is considered that this is the best method of removing all types of potential degradation products.

In addition, reclamation via ion-exchange resins is not considered to be a mature technology, and there are a number of disadvantages to its use, including:

- Ion-exchange resins have a limited life expectancy, and therefore will require replacement over time, increasing waste generation;
- Ion-exchange resins can be contaminated or otherwise have their performance affected by the presence of trivial anions such as carbonate and bicarbonate;
- Ion-exchange resins do not remove polymeric (uncharged) material and have a limited performance in the removal of metals; and
- Ion-exchange resins might produce more effluent than thermal reclamation, as the resins need to be recovered by flushing with dilute NaOH.

Thermal reclamation is also considered to be more energy efficient. The steam requirements for reclamation are much lower than for solvent regeneration, and therefore represents a comparatively small loading on the CHP plant. In addition, the vapour produced during reclamation will be fed directly into the CO₂ Stripper, thus recovering the energy employed for reclaiming back into the PCC plants.

Thermal reclamation is proven technology for the Cansolv DC-103 solvent to be used in the PCC plants, whereas other methods of reclamation have not been validated for this solvent.

4.2.6 CO₂ Conditioning and Compression

The gaseous CO₂ stream from the PCC plants will be saturated with water and will contain traces of oxygen which will need to be removed prior to export to the CO₂ pipeline and T&S network.

Each PCC plant will have its own integrally geared CO₂ compressor with integrated oxygen removal and dehydration unit. The compression stage prior to oxygen removal and dehydration is referred to as LP compression and after oxygen removal and dehydration, as high pressure (HP) compression.

The purpose of this part of the process is to condition the CO₂ captured in the respective PCC plant to the necessary temperature and pressure while also removing oxygen and water to meet pipeline specification prior to being sent to the export pipeline. The two units serving the PCC plants will have identical capacity and will combine upstream of the common final CO₂ cooling and metering station.

The specification for the conditioning equipment/ processes to enable the gaseous CO₂ stream to meet the purity requirements will depend on the specification for the CO₂ T&S network utilised however, it is envisaged that the LP compression will take the CO₂ to approximately 30 barg.

Prior to dehydration, oxygen is removed in a palladium/ platinum deoxygenation unit using hydrogen produced on site by the dissociation of water.

The dehydration unit a temperature swing adsorption process, comprising 2 or 3 beds of silica gel desiccant. It will operate in a cyclic manner such that when one bed is in dehydration mode, the other bed(s) are in regeneration or standby mode. Water removed during the compression process will be recovered and will be reused within existing cooling water system as make-up water, to both minimise water usage and wastewater generation.

The LP compressed CO₂ will be compressed further to 135 barg (pipeline pressure) and to dense phase for export, measured in a metering station and transferred into the T&S pipeline network (by third parties).

Cooling will be required in stages during the compression process.

The CO₂ Compression Systems will be provided with a single 40m CO₂ vent stack for the safe venting of CO₂ to atmosphere in the event of a process outage or emergency. The CO₂ vent will collect the discharge from vents and relief valves within the CO₂ Compression facilities and pass-through a vent knock-out drum (if HP) in which a CO₂ vent heater will be placed to ensure low temperature solids are prevented from forming, prior to reaching the CO₂ vent stack or sent directly to the vent stack (if LP).

The selected compressor is an integrally geared multi-stage compressor, which have not yet been widely deployed, and therefore potential for heat recovery is not fully understood. It is envisaged that integrating a heat recovery scheme to the compressors would introduce significant risk to the performance of the compressor, given its relatively limited industry experience and especially in PCC plant applications. However, the number of compression stages employed will be optimised to minimise heat rejection, and therefore it is envisaged that opportunities for heat recovery would be limited in any case.

4.2.6.1 Carbon Dioxide Export Metering

The quality of the CO₂ will be monitored for compliance with export specifications for the following parameters:

- temperature;
- pressure;
- water content;
- oxygen content;
- hydrogen content;
- carbon monoxide (CO) content;
- hydrogen sulphide content;
- SO_x;
- oxides of nitrogen (NO_x); and
- Amines.

There will also be a requirement for sampling and analysis of other components that are included in the export specification (including ammonia, formaldehyde, acetaldehyde, ethanol, combined methanol and ethanol, mercury, cadmium, thallium and total sulphur). In addition to quality monitoring, fiscal flow metering is to be provided for custody transfer of CO₂ sent to the export pipeline.

The limit of the proposed Environmental Permit is at the tie-in to the export T&S pipeline.

4.3 Abnormal Operation

During start up and shut down of the PCC plants (for example before and after a maintenance outage), when the required CO₂ specification cannot be achieved, CO₂ may need to be safely vented to the atmosphere.

On start-up, CO₂ from the PCC plants will need to meet the specification required by the onward T&S Network and it may take a limited period of time for the deoxygenation, dehydration and cooling process during compression to meet the required specification. As such CO₂ may be vented to atmosphere during this time. At this stage of the project design, it is not possible to determine how long venting may take, and this will be confirmed later during the detailed design process, however given the base load nature of the CHP plant for steam generation, it is envisaged that this will be an infrequent activity.

CO₂ venting may also be required during emergency situations to ensure safe operation of the PCC plants. A single CO₂ vent stack is therefore included, with the height of the emission point (40m) designed to ensure safe dispersion of the CO₂. Any venting required for the off-site T&S Network pipeline will be provided by the T&S Network provider and therefore will not be from the Installation.

In addition, CO₂ may also need to be vented in the event of a process upset. This will enable investigation and rectification of any issues within the PCC plants during ongoing operation, rather than requiring the PCC plants to shut down. In this event, CO₂ would be vented via CO₂ Absorbers' stacks, and if such a process upset cannot be remedied in a reasonable period of time, the PCC plant will be shut down, and the GT/ Aux Boiler flue gas will vent from the original stack (Emission Points A1 – A4).

The CO₂ compressors would need to be depressurised in the event of such an occurrence.

All CO₂ venting will be minimised as far as possible, as this will impact the effectiveness of CO₂ capture for the project as a whole. An assessment of the potential impacts associated with identified CO₂ venting scenarios has been carried out and is provided in Appendix H.

4.4 Utilities

4.4.1 Steam

The PCC plants will require LP steam for the operation of the CO₂ Stripper reboilers, Thermal Reclaimer preheater, Thermal Reclaimer column, the amine solvent storage tank and the fresh solvent tank.

MP steam will be required for the Thermal Reclaimer reboiler.

The steam requirements for the PCC plant will be met by the existing generating units at the Installation.

4.4.2 Water

Raw water will be required intermittently for the operation of the DCCs and the utility stations at the Installation.

Within the PCC plants, water utilisation will comprise demineralised water and raw water. Demineralised water is expected to be sourced from the existing Demineralised Water Tank and delivered by the existing demin water transfer pumps to its end users within the PCC plants. The demineralised water will be used for the following purposes:

- fresh solvent dilution (intermittent);
- 47% caustic dilution (continuous);
- dilution of Reclaimer waste (intermittent);
- maintaining the PCC plants water balance (intermittent); and
- hydrogen gas generation (continuous).

LP and MP condensate return will be associated with the steam usage (both LP and MP steam). It is noted that the process condensate from CO₂ compression and dehydration is clean and contains a small amount of dissolved CO₂. This water will be suitable for use within the process to dilute the fresh solvent and as such there may be an opportunity to reduce correspondingly the fresh demineralised water consumption; this will be confirmed during the detailed design stage.

Based on the expected flow rates for each user, it is estimated that the proposed operation will use approximately 180tpa of demineralised water. Raw water will only be required intermittently for use in the DCCs and therefore annual usage will be determined when the plant is operational.

The PCC plant is designed to recover and re-use waste water such that water intake is kept at existing levels for the Installation and not more than 10% of the existing maximum daily water intake if additional water is required, although this will be dependent on the amount of water reuse that is achievable.

Fire water and potable water will be provided via a tie-in and extension of existing Installation systems.

4.4.3 Cooling Systems

The PCC plants main requirement for cooling will be to lower the temperature of the flue gas coming from the GTs and Aux Boilers, prior to amine stripping. This will be carried out in the DCCs. Additionally cooling for the PCC plants will be required for the water wash cooler, the CO₂ Stripper condenser and the lean amine cooler. The CO₂ compressor systems will also require cooling.

An assessment of BAT for Cooling for the PCC plants is provided in Appendix E, which considers water-cooled, air cooled and hybrid systems. All options have been assessed on their ability to meet the operating requirements of the PCC plants, the availability of water, the area of land required, constructability, capital and operational costs and the engineering effort required.

Cooling for the PCC plants will be provided by Air Coolers, as it is considered that this is the most appropriate method taking into account the findings of the BAT assessment.

Air cooling provides cooling by passing a flow of air over banks of finned tubes which contain the medium to be cooled. These banks of heat exchangers are normally mounted in an elevated structure to allow good and even air flow across the heat exchange surfaces; the air flow is created by large fans.

Air cooling requires no off-site infrastructure and relies solely on the supply of electrical energy to operate the fans. Whilst this represents a slightly higher parasitic load than for some cooling options, this is offset as there is no requirement to pump cooling water. The heat-transfer characteristics of the air-cooled heat exchangers, and the fact that the air temperature is normally higher than water-cooled options, means that this is typically the least favourable arrangement for generation plant efficiency, but the efficiency difference is minor for non-steam condensing systems, such as a PCC plant.

Air cooling has the disadvantages of the noise generated by the fans and the larger footprint required to achieve the necessary level of cooling, however, it also offers benefits, such as avoiding the environmental impacts associated with water abstraction and discharge as well as the construction effects of the associated pipework infrastructure; and heat is discharged directly to the air without the generation of visible plumes created by wet methods. It is recognised as part of the BAT assessment that water availability is constrained in the Humber region, that the Humber Estuary is an internationally designated site and that there is currently no outfall from the Installation suitable for the discharge of spent cooling water.

4.4.4 Compressed Air Systems

Compressed air will be provided by a new instrument air system. This will be connected to the existing Installation instrument air system header for utmost flexibility.

4.4.5 Amine Solvent Storage

There will be one main Amine solvent storage tank (approximately 2,000m³) for both PCC plants, which under normal operation will be empty. The purpose of the tank is to hold the entire inventory from one of the PCC plants, with some margin for flushing, so that the PCC plants can be drained down for maintenance activities to be carried out. Following maintenance, this solvent would be returned to the PCC plants.

Fresh solvent for use in the process will be delivered to the smaller (approximately 74m³) fresh solvent storage tank, from where fresh solvent will be pumped to the Lean Solvent Flash Vessel or CO₂ Absorber bottoms, as required. LP steam heating will be provided to the fresh solvent storage tank for winterisation.

Additional considerations for the storage of amines include the potentially high reactivity of the solvents, leading to corrosion of some metals, and generation of degradation products. The materials of construction for the amine storage and dilution tanks and pipework materials will be confirmed during the detailed design process, however it is anticipated that this is likely to include Carbon Steel + Stainless Steel Cladding and atmospheric pressure fixed roof tanks. Further information is provided in Section 4.10.

The amine solvent to be used in the PCC plants has a low volatility. Its boiling point is 105°C, i.e. higher than water, and it has a very low vapour pressure of <0.13 hPa at 20°C. Although it is described as having a 'sweet' odour, it is considered that due its low volatility there is minimal potential for odour issues to arise from storage or delivery operations. As such, it is not considered that abatement is required on the breather vent for the storage tank, nor that back venting for tanker deliveries will be required.

4.5 Process Control

The existing Control Building allows VPI operators to control the Installation 24 hours per day, during normal and emergency operation. It is anticipated that the existing Control Building will be expanded to accommodate the controls required for the PCC plants.

Similar to the existing controls, the PCC plants will be controlled 24 hours per day, with process information displayed to the operators to identify any issues and trigger maintenance and repairs as needed.

The PCC plants will be highly automated and will be controlled via a Distributed Control System (DCS), providing monitoring and control. The design philosophy of the DCS is to provide the maximum possible level of automation for all systems installed and the plants will, in general, operate automatically under operator supervision during normal operation.

Semi-automatic sequences and manually requested actions will also be available via the DCS when required, for instance operator intervention may be required to maintain minimum utility flows by the opening of equipment by-passes or shutting down unnecessary equipment (e.g. cooler fans, circulation pumps, amine pumps). Generally, plant operations will be carried out from the operator desk in the control room. The DCS allows items, systems and the entire plant to be started, operated and stopped in a safe manner.

The DCS will display and record the plant operating parameters required for best practice process control and minimisation of environmental impacts. This information will be available on-line to the operator via the plant operating screens as instantaneous values, with historical data available via trend screens. The DCS will also include typical Continuous Emissions Monitoring systems (CEMS) information. CEMS will be in place for the demonstrating compliance with the LCP BAT-AELs for combustion exhaust gases of NO_x, CO, CO₂, SO₂, particulates on the inlet to the PCC plants. Additional CEMS will be in place for the monitoring of amines and their degradation products, in addition the air flow and moisture content from the PCC plant absorber stacks. CEMS for monitoring the gas being sent for compression will also be monitored. This information will also be available for offline analysis by operators and the site engineering team.

The PCC plants' operational data will allow the plant processes and maintenance procedures to be reviewed and optimised. The data available via the DCS will also allow reporting of plant performance and environmental compliance.

Furthermore, the DCS will provide the operators with a series of alarms should an operating parameter approach, or exceed, its control set point value. These alarms will be displayed on the appropriate plant operating screen as well as a dedicated alarm screen for operator review and relevant action.

The DCS will use control logic and trips to prevent an undesirable situation from occurring or continuing.

4.6 Management Systems

The Installation will continue to be operated in line with the existing Environmental Management System (EMS) for the Immingham CHP Power Plant, which is accredited to the requirements of ISO 14001:2015, and is compliant with the guidance set out by the EA. The EMS will be amended to include the operation of the PCC plants prior to commencement of their operation.

The EMS and procedures will be made available for inspection by the EA upon request, and will be applicable to all staff, contractors and visitors to the Installation. The EMS is developed to enable compliance with the Environmental Permit and other legislative requirements for the protection of the environment and human health.

4.7 General Maintenance

The objective of plant maintenance is to ensure that the Installation operates safely and reliably. Inspection and maintenance activities have been considered in the PCC plants' design and layout during detailed design. Areas for permanent laydown and turnaround areas for maintenance are included in the PCC plant area.

Routine maintenance at the Installation is planned and scheduled via the maintenance management system, with major overhauls occurring approximately once every two to five years depending on the nature of plant operations in that period.

The maintenance strategy to be adopted for the PCC plants will use established methods such as Risk Based Inspection (RBI) and Reliability Centred Maintenance (RCM) to support the required plant availabilities. Therefore, to support the maintenance strategy for the PCC plants, each major equipment item will be provided with appropriate access and overhaul laydown areas and the internal road layout will be designed to enable free movement for cranes and heavy lifting equipment.

It is anticipated that an integrated Operations and Maintenance (O&M) team will have responsibility for daily operations, including troubleshooting and effecting minor repairs on the PCC plants. Major and specialist O&M interventions are likely to be outsourced and major equipment items serviced by original equipment manufacturers (OEM).

4.8 Raw Materials

The use of hazardous materials will be eliminated by design where possible, and minimised where it is not practical to eliminate. Areas handling chemicals will be paved and kerbed/ bunded to ensure that spillages and/ or leaks in those areas are contained, manually cleaned up and removed for appropriate disposal off-site, in line with the existing Spillage Procedure VP11-ENV-PR-8135. All liquid chemicals stored will be kept in appropriately bunded and segregated areas. Furthermore, controls such as emergency isolation valves will be put in place to minimise the risk of discharges off-site from any spillages entering the Installation's surface water drainage system. Further detailed information on the storage and containment systems is provided in Section 4.10.

The principal raw material to be used in the PCC plants will be the amine-based solvent, Cansolv DC-103. There will be an initial quantity (first fill) of amine-based solvent and after which the PCC plants will include equipment for recovering and reclaiming the used solvent for reuse within the process, as described in Section 4.2.5, thereby minimising fresh solvent usage. The fresh solvent will be stored in an approximately 75m³ fresh solvent storage tank.

As stated in Section 4.4.5 there will be a large amine solvent storage tank (approximately 2,000m³), which under normal operation will be empty, and will only be used when the PCC plants need to be drained down for maintenance activities.

Caustic will be delivered as a 47wt% solution and will be diluted to 20wt% at the Installation.

Other raw materials in the PCC plants will be stored in small quantities in appropriate containers, within suitable spill protection including bunds, on bunded pallets, on drip trays, in specifically designed cabinets and cupboards or other appropriate storage units and areas. Additional hazardous materials will be supplied, stored and used in containers of 1 m³ or less.

Table 4.1 summarises the additional raw materials to be used by the Installation for operation of the PCC plants and the indicative location of the hazardous raw materials storage is shown in Figure 4 (Appendix A).

Table 4.1: Additional Raw Materials for use in the PCC Plants

Material	Purpose	Estimated Maximum Storage Quantity	Estimated Annual Consumption
47% Sodium hydroxide (caustic)	DCC wastewater stripper dosing and thermal Reclaimer pH control	10 m ³	220 tonnes
Cansolv DC-103 Fresh solvent	100% solvent delivery to site - CO ₂ scrubbing solvent.	74 m ³	Subject to commercial confidentiality.
Antifoam agent	Added to the re-circulating amine to prevent foaming in the Absorber.	1m ³ - Stored in IBCs	Extent of potential foaming not known until operation commences.
Oxygen removal catalyst	For use in Oxygen Removal Reactor	Not held on site, brought in for change over when required.	2.5 m ³ (based on replacement every 4 years)
Silica Gel	Dehydration Package	Not held on site, brought in for change over when required	12 m ³ (based on replacement every 4 years)
Activated Carbon	Solvent filtration units	Not held on site, brought in for change over when required	Extent of usage not known until operation commences

The PCC plant will use small quantities of additional water and it is anticipated this demand can be met with recovered water from flue gas condensation in the DCC. In the event the quantity of water recovered is inadequate, any increase in raw water intake is anticipated not to be more than approximately 10% of the existing Installation maximum daily raw water intake. Raw water is sourced from Anglian Water and there is a contracted maximum daily demand of 15,000 tonnes (600 tonnes/hour). Within the PCC plants there is water recovery and reuse where possible (as described in Section 4.4.2), to minimise additional water use.

Additional water demand for the PCC plants arises as a result of increased usage of demineralised water for steam generation and various other uses as detailed in Section 4.2.2. The quantity of water required is significantly reduced by re-using wastewater streams where possible.

4.9 Waste

The existing waste management procedures in place at the Installation will be reviewed and revised where necessary to ensure they cover the activities and wastes produced by the PCC plants. All waste generated as part of the PCC plants operation will be managed in line with the waste hierarchy and disposed of by licenced waste contractors where necessary.

Small quantities of non-hazardous operational waste will be generated from the operation and maintenance of the PCC plants, in addition to minor amounts of dry mixed recyclables and general domestic waste, similar to those generated by the existing Installation.

Hazardous waste from the Thermal Reclaimer (consisting of degraded amine, heat stable salts and corrosion products) will be generated and stored locally within the Degraded Solvent drum prior to transfer off-site. Routes for recovery of this stream will be investigated, however at present it is envisaged that disposal via off-site incineration at a licensed waste contractor's facility will be required.

There will be cartridges from the mechanical filters which will require disposal. The frequency and quantity will be dependent on the quantity of solids within the recirculating solvent, and therefore it is likely that more frequent changes will be required following initial plant start-up and after plant maintenance activities. During normal PCC plant operation, less frequent cartridge changes are anticipated. In addition, carbon from the carbon filters will also require changing, anticipated to be on a twice year frequency during steady operation. Prior to disposal offsite the carbon will be flushed with water.

Dehydration waste, i.e. silica gel, will be replaced once spent. The frequency of this will depend on operating experience, however it is anticipated to require replacement up to every 4 years.

Waste lubricating oils will be stored in the Installation's waste area within an oil tank which is bunded and has oil settlement traps. Where possible this waste will be recycled, otherwise it will be disposed of offsite.

All wastes will be stored in appropriate, labelled containers and stored in designated bunded waste storage areas. All bulk waste storage tanks will be within bunds with 110% capacity of the tank.

Wastes anticipated to be generated by the PCC plants operation, including estimated quantities and generation frequency i.e. continuous/ intermittent/ occasional, are shown in Table 4.2.

Table 4.2: Anticipated Waste Streams for the PCC Plants

Waste Stream	Estimated Annual Quantity	Generation frequency	Disposal Route
Thermal Reclaimer waste (degraded solvent)	2,760 tonnes	Continuous	Discharged to storage drum prior to disposal. Likely to be stored in batches of 10 - 15m ³ prior to collection for offsite disposal.
Solvent from Solvent Drain Vessel	Solvent will be re-used in the process wherever possible, and only disposed of if	Intermittent	Collection and disposal by 3 rd party via vacuum truck

Waste Stream	Estimated Annual Quantity	Generation frequency	Disposal Route
	cannot be re-used, therefore disposal quantity unknown.		
Oxygen Removal Catalyst	6.5 tonnes/ replacement	Occasional, expected to be replaced every 4 – 6 years	Removal and disposal by specialist 3 rd party contractor
Dehydration Desiccant	24 tonnes/ replacement	Occasional, expected to be replaced every 4 – 6 years	Removal and disposal by specialist 3 rd party contractor
Activated Carbon	113	Intermittent, expected to be every 12 months depending on filter performance	Intermittent waste streams. Mechanical filter elements and activated carbon from the filtration systems are likely to be hazardous in nature and will require disposal offsite by 3 rd party contractor.
Waste lubricants	~5	Intermittent	Intermittent waste stream. Stored in Site Waste Area oil tank disposed of offsite by 3 rd party contractor.

4.10 Containment

The Ciria 736 guidance⁴ provides guidance to Operators on the identification and management of potential risks associated with the storage of hazardous substances and their potential impact on the environment. To effectively address these risks, the guidance recommends the use of a source pathway receptor model to assess whether there is a source, a receptor and a pathway by which the source material could reach the receptor. Using the Guidance, the outcome of the model can be used to provide a site hazard rating (low, moderate or high) depending on the potential risk. The risk assessment then considers the likelihood of a loss of containment which is then combined with the site hazard rating to provide an overall site risk rating.

The Guidance outlines a three-tiered classification framework (Class 1, 2 and 3) each representing a different level of integrity of secondary and tertiary containment to match the different requirements of high, moderate and low overall site risks. The classification system recommends different standards of construction, or levels of performance in accordance with each of the three levels of risk. A low-risk site is Class 1, moderate is Class 2 and a high-risk site is Class 3. The site risk rating informs which of the three-tier risk-based classifications the site falls within. The primary goal of the containment system, as outlined in the guidance, is to effectively mitigate the potential pathway between a source and receptor.

Based on the risk assessment framework, the site is considered to Class 1, although this will be reviewed during detailed design.

The site is a lower Tier CoMAH site due to the storage of distillate fuels and therefore has defined procedures in place for inspection and maintenance of storage tanks and bunds.

The three main storage tanks (caustic, solvent storage (for use during maintenance only) and the fresh solvent storage) will be located within a single bund located in the Chemical and Bottle Compound area to the west of the PCC plant area.

During the design stage of the project, Hazard Identification (HAZID) studies have been carried out to assess potential risks associated with the storage and use of the chemicals to be used as part of the PCC plants. Through this process, all raw materials and wastes that are considered to represent a potential hazard to the environment in the event of a spill/ leak will be located within appropriately

⁴ CIRIA (2014). Containment Systems for the Prevention of Pollution, Secondary, tertiary and other measures for industrial and commercial premises – CIRIA C736.

designed storage tanks with bunds, sized to either be 110%, where the bund contains a single vessel or 25% of the total volume of all tanks within the bund where multiple tanks are present, in line with the requirements of the CIRIA C736 guidance.

At this stage in the project's design, specific details of materials of construction for tanks and bunds are not finalised, however all materials of construction for primary and secondary containment will be selected to ensure compatibility with the stored liquids in each primary containment tank. In addition, bunds will be designed to ensure that pipework does not penetrate the bund walls and be designed so as to catch leaks from tanks or fittings.

Primary and secondary containment systems at the Installation are regularly inspected and maintained as detailed in the Installation's EMS and described in Sections 4.6 and 4.7 of this Supporting Document, and this will be expanded to cover the PCC plant area. Such measures include: regular visual inspections and emptying of rainwater regularly to maintain the containment capacity and programmed engineering inspections.

Details of the storage and containment arrangements, based on the current design, are provided in Table 4.3.

Table 4.3: Bunding and Containment Arrangement for Bulk Storage

Tank	Primary Containment				Secondary Containment		Tertiary Containment
	Size	Bund Dimensions	Material of Construction	Other info	Bund Dimensions	Bund construction	
Caustic	3m diameter 3.6m height	22m ³ max capacity 6m ³ working capacity	Carbon steel internal lining of DERAKANE 411 Epoxy Vinylester or equivalent	Overflow line to bund Level gauge High level alarm High-high level trip	10.4m x 18.6m x 2.4m (L x W x H) Bund is at least 110% of working volume	All bunds will be constructed/ lined with materials that are impervious to the tank contents to prevent seepage to the ground. Such materials have not yet been confirmed, however this information can be provided to the EA when detailed is complete, as part of a pre-operation condition in the Environmental Permit, if required.	The PCC plant area will be surfaced with impervious materials where there is a risk of accidental pollution from equipment failure, or spillages. The PCC plant area is designed to drain to the M4 holding pond located at the south-east of the development. Concrete used for kerbed slabs, drainage ditches and the M4 holding pond are to be designed as water excluding. Expansion joints will be provided with flexible sealant and water-bars as necessary to complete the system.
Solvent storage tank (only in use during PCC plant maintenance)	15m diameter 14.4m height	2,330m ³ max capacity 1,900m ³ working capacity	Carbon steel with stainless steel lining or Fibre reinforced polymer (FRP) lining	Overflow line to bund Level gauge High level alarm High-high level trip	30m x 27m x 2.4m (L x W x H) Bund is at least 110% of working volume		
Fresh solvent tank	4.5m diameter 7.2m height	107m ³ max capacity 74m ³ working capacity	Carbon steel Internal coating to be confirmed by supplier	Overflow line to bund Level gauge High level alarm High-high level trip	12.9m x 18.6m x 2.4m (L x W x H) Bund is at least 110% of working volume		

4.11 Energy Efficiency

The PCC plants, including CO₂ compression plant, represent a parasitic load on the existing CHP plant and therefore optimised integration of utilities for energy efficiency is paramount to maximising the overall CO₂ reductions of the project as a whole.

The overall performance of the PCC plants for optimised energy efficiency depends on the integration, as far as practicable, of electrical, steam and water circuits. The Cansolv DC-103 solvent and associated process configuration was selected to maximise energy efficiency.

At present, under the existing Environmental Permit, the Installation is required to monitor the combustion process for energy efficiency; it is expected that this will continue to be required.

The PCC plants will lead to a decrease in the overall energy efficiency of the Installation due to the additional parasitic load, however, it is considered that integration of the PCC plants with the existing GTs and Aux Boilers would be more efficient than a separate PCC plant, since this limits losses during transfer of flue gases, and conditioning of the flue gases prior to reaching the PCC plants. In addition, the air-cooled systems for the PCC plants are to include forced draft fans to minimise heat recirculation so as to reduce the overall cooling load.

Additional measures for maximising energy efficiency of the Immingham CHP power plant with PCC plants installed will be investigated during detailed design.

The key interfaces for energy efficiency within the PCC plant, are considered to be:

- exhaust-gas pre-treatment including cooling, prior to the PCC plants, utilising DCCs and booster fans;
- use of steam supplied from the existing GT1 and GT2 steam turbines for solvent stripping (CO₂ Stripper reboiler), CO₂ de-oxygenator and solvent recovery (Reclaimer);
- steam condensate recovery from the PCC plants;
- integration of cooling water supply to Immingham CHP plant and the PCC plants to allow for variations in cooling loads across the system;
- electricity supply to the PCC plants from the Immingham CHP power plant (parasitic load); and
- implementation of a mechanical vapour recovery scheme to reduce steam demand by the PCC plant.

General measures to maximise energy efficiency across the PCC plants include:

- the plant components will be sized appropriately for the design capacity of the plant in abated mode, so that each element is operating optimally and efficiently;
- use of high efficiency motors and drives to minimise parasitic load;
- 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.

The PCC plants will also be subject to regular planned maintenance in order to optimise the efficiency of the equipment at the Installation.

Specific energy efficiency measures to be employed include:

- Mechanical Vapour Recovery (MVR) and condensate flash: Lean amine solvent and condensate will be flashed and returned back to the CO₂ Stripper. This effectively trades off electrical energy for heat energy. The benefits include reducing steam consumption by >25%, reducing the duty on the reboilers which can therefore be reduced in size.
- Condensate: Condensate at 100°C is returned to the deaerator where it is combined with lower temperature condensate return from other sources. The PCC plants' condensate provides required heating to achieve normal operating temperature of the deaerators, thereby reducing the need to use LP steam.

- Compression Heat: Integrally geared compressors will be used, which are energy efficient.
- A Steam Turbine Generator will be employed to produce LP steam whilst also producing additional power for local consumption or export.

The average temperature of the combined GT and Aux Boiler flue gas is 130°C. Flue gas heat is already recovered in the HRSGs, therefore there is no opportunity to recover the remaining residual heat.

The energy performance of the system will be further refined at detailed design stage.

4.12 Energy Use

The PCC plants are estimated to require approximately 100MWe of additional electrical energy and 98MW of additional steam, which will be provided by the VPI CHP Power Plant. This represents 50% of the Installation's total parasitic load.

The main electrical equipment to be used in the PCC plant includes:

- CO₂ Compressor –46,000kW;
- Pumps – 12,000kW;
- MVR Compressors – 11,400kW;
- Blowers – 10,800kW;
- Others (including instrumentation/ analysers/ control room/ trace heating etc.) - 10,300kW;
- Air coolers - 8,200kW; and
- lighting and small power, sockets etc - 1,300kW.

The main energy use for the PCC plants will be the CO₂ Compressors, however the integrally geared compressors to be used are considered to be the most energy efficient option available. It is estimated that the steam requirements of the PCC plants will be 300MWth (420 tonnes/ hour LP steam equivalent).

5. Emissions to Air, Water and Land

5.1 Emissions to Air

5.1.1 Point Source Emissions

Existing combustion emissions from the Installation occur from GT1, GT2 (NO_x and CO) and the two Aux Boilers (NO_x and CO, and when burning ROG, SO₂ and particulates) flues. At present, the emissions from these sources are released to air via dedicated flues (Emission Points A1, A2, A3 and A4), held within a single windshield (stack), which is 90m high.

Following the commissioning of the PCC plants, the normal mode of operation for GT1, GT2 and the Aux Boilers will be the CO₂ abated mode, with carbon capture taking place. As such, the existing flue gases will be diverted from the existing emission points to the PCC plants, where the CO₂ will be removed, and they will then be released via two new emission points located on top of the PCC plant Absorber columns (Emission Points A6 and A7).

Emission Points A6 and A7 will therefore be the primary source of emissions to air from these sources once the PCC plants become operational, with existing Emission Points A1 – A4 not being used under normal operation. These existing emission points will remain however, and will essentially become bypass vents for when the PCC plants are not operational (as detailed in Section 4.2).

The emissions from new Emission Points A6 and A7 will therefore comprise the combustion emissions of NO_x and CO from GT1 and GT2 and NO_x, CO, SO₂ and particulates from the Aux Boilers. In addition, there will be potential emissions of amines present within the Cansolv DC-103 solvent used within the PCC plants, and potential solvent degradation products may also be present.

The combustion emissions from the existing GTs and Aux Boilers are currently at the BAT-Associated Emission Levels (BAT-AEL) for the relevant technology type, (e.g. due to the differing technologies, gas turbines and boilers have different BAT-AELs) as detailed in the LCP BRef. There are no BAT-AELs for the combustion emissions from the combined sources that can readily be applied to the new Emission Points A6 and A7. There would be no formation of NO_x, CO, SO₂ or particulates within the CO₂ Absorbers.

As such, the assessment of the impacts of the emissions from the new Emission Points A6 and A7 have been based on the mass release rate (g/s) of NO_x, CO, SO₂ and particulates of the combined emissions from one GT and one Aux Boiler operating at full load with pollutant emission concentrations at the relevant BAT-AELs.

There are currently no BAT-AELs relating to the PCC process itself, and although the EA has provided BAT guidance for PCC plants, the guidance does not include any specific ELVs at this time, as it is intended that these will be developed once PCC plants become operational in the UK, and collated monitoring data can confirm suitable levels for which the BAT-AELs should be set. Emissions from the PCC plants are therefore based on levels that have been advised by the solvent supplier, as achievable emissions from their PCC process.

The data provided in Table 5.1 represents the proposed emission parameters for the PCC plants, as based on the current PCC plant design.

Table 5.1: Proposed Emission Parameters for the PCC Plants Absorber Stacks (A6 and A7)

Parameter	Absorber Stacks (each stack)
Stack height (m above finished ground level)	110
Stack locations (OS grid reference)	A6 - 516762, 417001 A7 - 516811, 416921
Appropriate flue diameter (m)	6
Volumetric flow at stack exit parameters (Am ³ /s)	620
Average efflux velocity (m/s)	21.9

Parameter	Absorber Stacks (each stack)	
	Annual Average	Hourly Average
Volumetric flow (Nm ³ /s)	828	
Average stack exit conditions	Temperature (°C)	44
	Oxygen (% dry)	10.9
	Moisture (%)	8.9
Assumed maximum operating hours / year for assessment purposes	8,760	
Oxides of nitrogen (NO _x) emission rate (g/s)	39.8	95.4
Carbon monoxide (CO) emission rate (g/s)	42.8	174.5
Sulphur dioxide (SO ₂) emission rate (g/s)	2.9	5.7
Particulate emission rate (g/s)	0.4	0.8
Ammonia (NH ₃) (mg/Nm ³)	2.0	-
Ammonia (NH ₃) emission rate (g/s)	1.7	-
Amine 1 and 3 (mg/Nm ³)	0.27	-
Amine 1 and 3 emission rate (g/s)	0.22	-
Amine 2 (mg/Nm ³)	0.03	-
Amine 2 emission rate (g/s)	0.02	-
N-amines (direct release) (mg/Nm ³)	0.0013	-
N-amines emission rate (g/s)	0.0010	-
Amide ELV (mg/Nm ³)	0.032	-
Amide emission rate (g/s)	0.027	-
Formaldehyde ELV (mg/Nm ³)	0.067	-
Formaldehyde emission rate (g/s)	0.056	-
Acetaldehyde ELV (mg/Nm ³)	0.20	-
Acetaldehyde emission rate (g/s)	0.16	-

¹ Concentration normalised to reference conditions: 273K, 101.3kPa, dry, 15%v/v oxygen

An Air Quality Impact Assessment (Appendix F) has been carried out for the operation of the PCC plants, comparing the impacts of the emissions detailed in Table 5.1 with those from the existing operation of GT1, GT2 and the two Aux Boilers, and the results are summarised in Section 7 of this Main Supporting Document.

It should be noted that although particulate emissions have been assessed at the existing permit ELV concentrations, recent flue gas characterisation monitoring has shown that the actual concentrations of particulates is very low.

The locations of the new Emission Points to air are shown in Figure 4 (Appendix A).

In addition to the two new emission points detailed above there will also be a CO₂ vent associated the Compressor plant (new Emission Point A8). The release of CO₂ from this vent would be abnormal operation, as previously detailed in Section 4.3. and an assessment of the impacts of the CO₂ venting releases has been carried out and is provided in Appendix H.

5.1.1.1 Visible Plumes

Due to the initial water content of the emission from the PCC plants, and the relatively low temperature of the release, there is potential for the plume from the Absorber stacks to be visible.

The potential for visible plumes to impact local receptors (including loss of light and ice on roads from plume grounding) has been reviewed with consideration of the frequency, length and direction of visible plumes generated during daylight hours with reference to local sensitive receptors, and is provided in Appendix F and is summarised in Section 7.3.1.4.

5.1.2 Fugitive Emissions

Fugitive emissions have the potential to occur from tanks, flanges, seals and equipment vents during transfer operations and during unloading operations from tankers. The PCCs plant will be designed such that items where fugitive emissions could occur will be specified as low emission items wherever possible, with suitable packing/ seals etc. Seal-less or dual seal pumps will be utilised for liquids with high vapour pressure.

A number of design measures will be implemented to avoid or minimise plant wide fugitive emissions; these include, but are not limited to:

- control valves in hydrocarbon service to be specified as low emission valves;
- risks from leaks shall be reduced by minimising the number of flanged joints, valves and connections to as low as practicable (ALARP) levels;
- design of tank roofs to minimise emissions (fixed roofs);
- dry gas seals on the CO₂ compressors where possible;
- high integrity compressor and pump seals for high pressure system;
- provision of reliable early leak detection and repair systems (LDAR);
- closed drains for drainage of hydrocarbon system; and
- venting of gases from process facilities, utility units, storage and unloading/ loading activities will be minimised and where possible routed to knock-out pots.

5.2 Emissions to Water

5.2.1 Point Source Emissions

5.2.1.1 Existing Installation Drainage

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

- Holding pond M1 collects process water from the existing Installation, mainly blowdown from the cooling water circuit, which is held and tested, and if acceptable is pumped to M2.
- Holding pond M2 collects surface water drainage from the existing Installation and where there is potential for oil contamination to occur, the drainage system goes through an oil/ water interceptor. Waters from holding ponds M1 and M3 are discharged to holding pond M2 prior to discharge.
- Holding Pond M3 collects the condensate from the steam cycle from the Installation, and the water is tested and discharged to M2.
- From holding pond M2, the combined wastewaters are discharged to the existing South Killingholme Drain outfall (Emission Point W1, NGR 517000, 417190), the location of which is shown in Figure 2 (Appendix A).

The existing Environmental Permit includes emission limits and monitoring requirements for Emission Point W1, including a maximum daily flow rate and limits on pH, temperature, oil, ammoniacal nitrogen, total suspended solids, chemical oxygen demand (COD) and dissolved oxygen. Quarterly returns to the Environment Agency during 2022 demonstrated compliance with the current emission limits for this release point.

5.2.1.2 PCC Plant Area Drainage

The key objectives of the PCC plant area drainage and effluent systems are to:

- provide a drainage system which is inherently safe;
- ensure compliance to relevant environmental and regulatory standards;

- ensure segregation of solvent drainage to ensure this does not enter surface water systems, and to enable recovery of the solvent where possible;
- provide high reliability and continuous operation year-round through minimisation of reliance on rotating equipment by employing gravity drainage where practicable; and
- make provisions for drainage requirements during normal operation, maintenance activities and emergencies.

The PCC plant area will result in clean surface water run-off, potentially contaminated surface water run-off and process effluents.

The drainage systems associated with the PCC plant area will have a single level of primary treatment available via a Class 2 Oily Water Separator (designed to achieve 100mg/l of oil) and two potential routes for disposal; either via a new balancing pond (M4) and high efficiency Oily Water Separator (Class 1 designed to achieve 5mg/l of oil) to a new site outfall (Emission Point W2 - NGR 517130, 417000) to South Killingholme Drain or, contaminated process effluents will go to a Drain Drum which will be emptied when required via vacuum truck for off-site disposal via a licensed waste contractor. As such, only clean surface water run-off and non-contaminated process waters will be disposed of via the new Emission Point W2 to South Killingholme Drain.

There will be three different drainage systems provided for the PCC plant area, comprising of:

- Surface water drainage for uncontaminated surface water run-off,
- Potentially Contaminated Surface Water (PCSW) surface water drainage (non-amine) for potentially contaminated wastewater from various process areas; and,
- Closed drainage for wastewater potentially contaminated with amines.

A flow diagram detailing the drainage systems for the PCC plant area is provided in Figure 6 (Appendix A) and further descriptions of the various drainage systems for the PCC plant area is provided in the Sections below.

Controls will be in place in the form of valves within the drainage systems to ensure contaminated wastewater is not released into the surface water drainage system without prior testing to ensure that they are not contaminated.

The only BAT-AELs specified for emissions to water in the LCP BATc are associated with direct discharges to a receiving water body from flue gas treatment activities, and therefore are not considered to be relevant to the wastewaters generated at the Installation. In addition, there are no BAT-AELs in the CCS BAT Guidance. As such, there are no additional process specific treatment options identified as BAT for the Installation.

As there is a proposed new Emission Point (W2) associated with this variation, Application Form C6 has been submitted with the application. Question 5 on the form requires justification for not discharging via foul sewer. W2 will take uncontaminated surface water drainage and PCSW which will have been tested to ensure that they fall within the proposed emission limits as detailed in Section 6. This is in line with the Installation's existing Emission Point W1, which releases similar waters from the existing VPI Immingham CHP Power Plant Installation.

The discharge will be into South Killingholme Drain, which takes the site's existing waters from Emission Point W1 and other discharge waters from the adjacent Humber Refinery site, which then flows to the Humber Estuary at South Killingholme Haven. It is considered that South Killingholme Drain therefore largely acts as a drainage channel for these sources prior to discharge into the Estuary. As such, it is not considered necessary to discharge the proposed uncontaminated surface water drainage and process waters to foul sewer.

5.2.1.2.1 Uncontaminated Surface Water Drainage (Storm Water Drain)

The storm water drain will collect:

- rainwater from non-contaminated areas, building roofs, parking areas and areas of hard-standing;
- clean/ non-contaminated water from bunded and kerbed areas, with controlled outlets; and
- fire-fighting water from fire-fighting in non-segregated areas.

Non-contaminated rainwater run-off from roofs, roads, and grade areas will be collected by a network of surface water ditches in the PCC plant area and will be routed through a Class 2 oily water separator prior to being collected in a new surface water holding pond (M4) and directed to new Emission Point W2, via a Class 1 oily water separator into the South Killingholme Drain, as shown in Figure 6 (Appendix A).

Tank bunds and areas of potential contamination (kerbed areas) will be connected to the surface water drainage through valved outlets to provide control over the quality of discharge. The valve will be kept closed. Following periods of rainfall, the collected water will be tested, in line with current Installation procedures, to determine if it is contaminated. Uncontaminated surface water will be discharged to the storm water drain, while contaminated surface water will be removed by vacuum truck for off-site treatment/ disposal by a third-party licenced waste contractor. The testing carried out will be dependent on the source of the surface water and the potential contaminants that could be present, for example, if there is a risk of amine contamination Total Organic Carbon would be tested for.

Outflow to the new Emission Point W2 will be limited to greenfield run-off rates.

During normal operation, the DCC blowdown water will be returned to the Raw Water Tank for treatment in the demin plant for reuse on site, however there will also be provision for this stream to be diverted to the M4 holding pond and discharged through W2 to South Killingholme drain, for in the unlikely event that the Raw Water Tank is full. It is considered that such an occurrence would be very rare and therefore would represent an abnormal operation. It is anticipated that the duration of such a release would be limited to 2 hours in most cases.

The DCC blowdown water will be 99.99% water, hence enabling its normal routing to the demin plant for reuse on site, however there is potential for trace sodium sulphate salts to be present due to the additional of caustic to the DCC to remove SO₂ from the Aux Boiler flue gas when firing on Refinery Off-gas. The composition of the DCC water is shown in Table 5.2.

Table 5.2: Composition of the DCC Water

Parameter	Quantity
Flow rate	1,900m ³ /day or 160m ³ in 2 hours
Temperature	30°C
Water	99.99%
NaHSO ₃	55.4ppm
Na ₂ SO ₃	20.5ppm

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

5.2.1.2.2 Potentially Contaminated Surface Water

The Potentially Contaminated Surface Water (PCSW) drainage system will collect surface water run-off from areas that are at risk of contamination with hydrocarbons (such as compressor lube oils) and chemicals. It will not collect waters that are at risk of contamination with amines (detailed in Section 5.2.1.2.3).

The PCSW catchment areas will comprise areas around process equipment handling hydrocarbons, solvent or chemicals, which would normally be clean, but are bunded or provided with local collection sumps as they represent a risk of contamination of the PCSW system due to infrequent maintenance activities. Such areas will be provided with passive diversion chambers and a local off-line interceptor sump, with isolation.

The interceptor sumps will be designed to collect the first flows in a storm and will be provided with means (i.e. pumps) to remove storm water after testing. Non-contaminated surface water will be routed

to the PCSW drainage and the Class 2 oily water separator prior to the new surface water holding pond (M4) for discharge via new Emission Point W2.

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

The following prevention measures will be used to reduce/ avoid contamination of surface water:

- daily checks for chemicals and oil leakage, to be included in site operating procedures;
- periodic sampling of storm water in each area before sending to the holding pond;
- installation of drip trays under pumps; and
- installation of pans and shrouds for plate heat exchangers.

5.2.1.2.3 Process Wastewaters – Closed Drainage

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

Equipment that does not contain amines will have liquid levels reduced as far as practical before being drained to a drain drum. Any fluids collected in the drain drum will be tested and be removed from site by tanker if they are contaminated, or if they are uncontaminated, will be discharge to the PCSW drainage system and the Class 2 oily water separator prior to discharge to the holding point M4 for release to Emission Point W2.

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

5.2.1.2.4 Firewater Management

The whole PCC plant area is designed to drain towards the M4 holding pond in the south-east corner of the site. In the event of a fire, the M4 holding pond will be closed off via an automatic penstock gate which will be linked to the fire alarm system to enable automatic closure, preventing contaminated fire water from being released via W2.

Firewater run-off from non-segregated areas will enter the surface water drainage system. Firewater from segregated areas will be collected within tank bunds and potentially, partially or wholly contained within kerbed areas, depending on the volume of firefighting water used.

All collected firewater will be analysed prior to either releasing to the M4 holding pond for discharge if uncontaminated, or will be collected for off-site disposal via a licensed third-party waste contractor if it is contaminated.

5.2.2 Fugitive Emissions

Areas handling chemicals will comprise hardstanding and be kerbed/ bunded to ensure that spillages and/ or leaks in those areas are contained, manually cleaned up and removed for treatment off-site. To minimise rainwater collection (and therefore inventory), these areas will be located indoors or be provided with rain shelters, where practicable and safe to do so.

Road tanker unloading areas will have the kerbed/ bunded areas sized to hold the full inventory of the tanker, in line with the CIRIA guidance in the event of a full loss of containment.

5.3 Emissions to Sewer

There will be no emissions to sewer from the operation of the PCC plants.

5.4 Emissions to Land

There will be no process emissions to land as a result of this Environmental Permit variation. All proposed processes will be undertaken on hard and impermeable flooring.

5.5 Odour

The potential for odour to occur from the PCC plant is dependent on the volatility of the Cansolv DC-103 solvent. Cansolv DC-103 has a low volatility. Its boiling point is 105°C, i.e. higher than water, and it has a very low vapour pressure of <0.13 hPa at 20°C. Although it is described as having a 'sweet' odour, it is considered that due its low volatility there is minimal potential for odour issues to arise through its use.

5.6 Noise

The PCC plants will include several key plant and equipment which could lead to noise emissions without appropriate mitigation.

The PCC plants have been designed such that, where possible, plant and equipment will be below 85 dB $L_{Aeq,T}$ at 1m. There are a number of key plant items which may have sound level inputs at this level including:

- CO₂ Absorbers exhausts;
- DCC pumps and pumps associated with the CO₂ Absorbers (i.e. water wash pump, solvent pumps etc);
- thermal reclaimers vacuum package;
- flue gas booster fans;
- compressors;
- hydrogen generation package; and
- air coolers.

Noise mitigation for the PCC plants has not been fully confirmed at this stage of the project as not all equipment vendors have been identified. However, consideration of operational measures, equipment specification, noise attenuation and locating of equipment, in line with indicative BAT for LCP will be made throughout the more detailed design phases.

Low noise fans on the air coolers, have been specified, and further specific noise mitigation measures will be developed during detailed design.

An assessment of the potential noise impacts has been completed, based on a number of worst-case assumptions given the early stage of design, and is provided in Appendix I of this document. Due to the assessment being based on early design information, it is proposed that the Noise Impact Assessment (NIA) be updated when further information is available following detailed design.

In addition, a draft Noise Management Plan (NMP) has been developed for the Installation, however again, this may need updating following confirmation of the final plant design. Once finalised, the NMP will be integrated into the existing EMS. The EMS already contains procedures related to the operation and maintenance of plant and equipment so as to minimise the emission of noise. These procedures will be extended to cover the PCC plants.

It is suggested that a requirement to update both the NIA and NMP following detailed design is included in the permit as a Pre-operational Condition.

A copy of the draft NMP has been provided with this application (Appendix J).

6. Monitoring

6.1 Infrastructure

An infrastructure monitoring plan is in place at the Installation, so as to protect the soil and groundwater beneath the Installation Site.

Regular inspection of all Installation infrastructure associated with bulk storage of oils and chemicals is undertaken, and will be extended to cover the PCC plants' area. Routine infrastructure audits comprise identification of issues relating principally to:

- minor leaks;
- standing water in bunded areas; and
- tank bunds.

Any issues identified during these inspections are recorded and actions assigned to relevant personnel and closed out once they have been actioned. The management systems will be extended to cover the operation of the PCC plants, and all its associated equipment.

Process monitoring will be undertaken at key stages of the process for a suite of determinands, including flow rate, temperature, pressure and concentrations of CO₂, H₂O, O₂, SO₂, NO_x. This will be used to optimise operation of the PCC plants' process.

6.2 Emissions to Air

6.2.1 Point Source Emissions

CEMS are currently in place on the emission points for GT1, GT2 and the two Aux Boilers to monitor the following species:

- Oxides of Nitrogen (NO_x);
- Carbon Monoxide (CO)
- Sulphur Dioxide (SO₂) (Aux Boilers only);
- Particulates (Aux Boilers only);
- Oxygen (O₂);
- Water vapour; and
- Temperature.

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

The GTs and auxiliary boilers are classified as LCP under the IED and therefore must meet the BAT-AELs detailed in the associated BATc document. As stated in Section 5.1, BAT-AELs for CCGTs and boilers differ, due to the different technologies resulting in different emission concentrations and also the reference conditions used to calculate released emission concentrations differ. As each PCC plant will take the flue gases from one GT and one aux boiler it will not be possible to demonstrate ongoing compliance with the relevant LCP BAT-AELs if these were monitored at the PCC plant absorber stacks. As such, it is proposed that combustion emissions from the GTs and auxiliary boilers will be monitored prior to their introduction into the PCC plant and therefore no change to the emission limits applied in the existing Environmental Permit to these sources are required. There would be no formation of NO_x, CO, SO₂ or particulates within the CO₂ Absorber and therefore there would be no requirement for further monitoring for these pollutants from the CO₂ Absorber stacks.

Only monitoring for any additional pollutant species that result from the PCC plants will then need to be monitored on exit from the PCC plant stacks.

As detailed in Section 5.1.1, there are three new Emission Points to air associated with the PCC plants, comprising:

- A6 – PCC Plant 1 Absorber Stack main release during normal (abated) operation (110m above ground level);
- A7 – PCC Plant 2 Absorber Stack main release during normal (abated) operation (110m above ground level); and
- A8 - CO₂ Emergency relief vent.

These emission points will be added to the existing Installation emissions monitoring plan.

Sample locations will be compliant with the requirements of the EA's M1 Stack Monitoring Guidance, as far as reasonably practicable. CEMS will be employed on the GT1, GT2 and the two Aux Boilers ducting prior to the PCC plant to monitor LCP combustion gases (NO_x, SO₂, CO and particulates), as required in the existing Environmental Permit for the Installation. As stated in Section 5.1.1, there are no BAT-AELs for the combined combustion emissions from the GTs and Aux Boilers, either in the LCP BRef or the CCS BAT Guidance, that can be readily applied to the new Emission Points A6 and A7 and therefore there should be no additional requirement to monitor these species from these release points.

Additional monitoring for pollutant species related to the operation of the PCC plants will be provided on the PCC plant stacks and include ammonia, amines, N-amines and VOCs. It is anticipated that monitoring of these species will also be carried out by CEMS, provided that available technologies are compatible with the amines within the Cansolv DC-103 solvent. Where this is not possible, periodic extractive monitoring will be carried out.

Given the that CCS is still an emerging technology, there are currently no recommended monitoring methodologies available. To assist with this, the EA commissioned the National Physical Laboratory (NPL) to develop periodic monitoring methods for amines and breakdown species, and the NPL has recently published a review of possible monitoring techniques⁵. The review details potential for Fourier Transform Infra-red (FTIR) and Proton Transfer Reaction-Time of Flight-Mass Spectrometry (PTR-TOF-MS) to be appropriate for monitoring amine and nitrosamine emissions, as it is capable of measuring down to parts per trillion levels, however it is not widely established nor commercially available.

In addition, the NPL review describes extractive monitoring techniques by collecting samples in solution (e.g. sulfamic acid) filled absorbers or sorbent tubes, however due to the saturated nature of the flue gas and the requirement for sorbent tubes to have a dry sample, the first technique is favoured. Limits of detection are a concern, as degradation products are predicted to be present at very low levels in the PCC flue gas.

The review detailed the limitations of potential monitoring methods. For continuous monitors, the heated sample lines required due to the presence of water would be likely to lead to the degradation of nitrosamines. Alternative condenser systems would remove nitrosamines due to their solubility. PTR-TOF-MS was largely discounted due to not being commercially available.

Extractive sampling techniques were therefore favoured in the NPL review, and a laboratory trial has since been carried out to gather more information into the knowledge gaps, such as the effect of temperature on degradation, and handling and storage conditions, and whether these effect the sample. This has resulted in a proposed methodology using impingers, which was found to be suitable for a wide range of nitrosamines, but not to low volatile compounds. At the time of submission of this application, the methodology was not available.

The solvent licensor has trialled the use of PTR-TOF-MS on several pilot plant campaigns, and it has been found to bring significant benefits in terms of limit of quantification of emissions (ppbv level), as well as the range of contaminants that can be monitored, with the possibility to perform full spectrum monitoring. However, at present PTR-TOF-MS cannot yet be used for real-time monitoring, as the instrument output data must be analysed and validated by specialised third parties – in the case of the pilot plant trial carried out for Shell, the University of Oslo. It is however understood that the instrument Original Equipment Manufacturer are developing commercial versions that may become available in the timeline of the Humber Refinery PCC plant start-up. The results obtained by the solvent licensor's monitoring campaigns have been published in several articles:

⁵ National Physical Laboratory (2022) Review of Emissions from Post-Combustion Carbon Capture using Amine Based Technologies and Current monitoring Techniques. Available: [Microsoft Word - Review of emissions from PCCC v3.1.docx](https://www.ukccsrc.ac.uk/microsoft-word-review-of-emissions-from-pccc-v3.1.docx) ([ukccsrc.ac.uk](https://www.ukccsrc.ac.uk))

- Performance of an amine-based CO₂ capture pilot plant at the Fortum Oslo Varme Waste to Energy plant in Oslo, Norway. Johan Fagerlung and al., International Journal of Greenhouse Gas Control 106 (2021).
- Recent Improvements and Cost Reduction in the CANSOLV CO₂ Capture Process. Karl Stéphenne and al., 16th International Conference on Greenhouse Gas Control Technologies, GHGT-16 - 23rd - 27th October 2022, Lyon, France.
- PPB-level monitoring of amines and NO₂ at the Klemetsrud CO₂ capture pilot plant. Bapriste Languille and al., 16th International Conference on Greenhouse Gas Control Technologies, GHGT-16 - 23rd - 27th October 2022, Lyon, France.

Several extractive sampling and analysis techniques have also been used to monitor emissions of the Cansolv systems. They rely on an impinger train isokinetic sampling, essentially modified EPA method 5, as described for example by Ramboll Analytics (Analysis and sampling methods – post-combustion CO₂ capture processes) or Technology Centre Mongstad and reviewed by the NPL. Such techniques have been found suitable for capture of amines and nitrosamines emitted by the Cansolv system. Liquid chromatography-mass spectrometry (LC-MS) methods have been used to analyse the samples collected in many pilot campaigns, while Saskpower has also used Ionic Chromatography for amines concentration and LC-MS for nitrosamines concentration.

Further work is required, both by the NPL and Shell, to identify appropriate monitoring techniques. It is therefore proposed that a Pre-operational Condition is included in the Environmental Permit to require VPI to confirm the proposed monitoring techniques for amines and degradation products from the PCC plant Absorber (Emission Point A6c) prior to commissioning of the PCC plant.

Table S3.1 of Schedule 3 of the Environmental Permit details the emissions and monitoring from all the existing emission points at the Installation. The list of new Emission Points and the proposed monitoring to be carried out is shown below in Table 6.1.

Article 15(5) of the Industrial Emissions Directive (IED) allows for a derogation from BAT-AELs for the testing and use of emerging techniques for a period not exceeding 9 months. As the PCC plant will be a FOAK plant, it is therefore considered that some provision for flexibility with new ELV compliance should be made during the commissioning period.

Table 6.1: Proposed Monitoring for the New Point Source Emissions to Air

Emission Point Ref	Parameter	Source	Proposed Emission ¹	Reference Period	Monitoring Frequency	Monitoring Standard		
A6	Ammonia (NH ₃)	PCC Plant 1 Absorber Stack	2 mg/Nm ³	Yearly average	Continuous	BS EN 14181 or NPL method under development.		
	Total Amines		0.3 mg/Nm ^{3 2}	Yearly average	Continuous if suitable CEMS are developed by PCC plant start-up, otherwise extractive monitoring methodology under development by NPL.			
	N-amines		0.0013 mg/Nm ^{3 2}	Yearly average				
	Amide		0.03 mg/Nm ^{3 2}	Yearly average				
	Formaldehyde		0.07 mg/Nm ^{3 2}	Yearly average				
	Acetaldehyde		0.20 mg/Nm ^{3 2}	Yearly average				
	Temperature		-	-			Continuous as appropriate to reference	Traceable to national standards
	Pressure		-	-			Continuous as appropriate to reference	Traceable to national standards
	Oxygen		-	-			Continuous as appropriate to reference	BS EN 14181

Emission Point Ref	Parameter	Source	Proposed Emission ¹	Reference Period	Monitoring Frequency	Monitoring Standard
	Water vapour		-	-	Continuous as appropriate to reference	as to BS EN 14181
A7	Ammonia (NH ₃)	PCC Plant 2 Absorber Stack	2 mg/Nm ³	Yearly average	Continuous	BS EN 14181
	Total Amines		0.3 mg/Nm ^{3 2}	Yearly average	Continuous if suitable CEMS are developed by PCC plant start-up, otherwise extractive monitoring methodology under development by NPL.	BS EN 14181 or NPL method under development.
	N-amines		0.0013 mg/Nm ^{3 2}	Yearly average		
	Amide		0.03 mg/Nm ^{3 2}	Yearly average		
	Formaldehyde		0.07 mg/Nm ^{3 2}	Yearly average		
	Acetaldehyde		0.20 mg/Nm ^{3 2}	Yearly average		
	Temperature		-	-	Continuous as appropriate to reference	Traceable to national standards
	Pressure		-	-	Continuous as appropriate to reference	Traceable to national standards
	Oxygen		-	-	Continuous as appropriate to reference	BS EN 14181
	Water vapour		-	-	Continuous as appropriate to reference	BS EN 14181

¹ The limits do not apply during periods of shut down or start up.

² Proposed emissions are provided at the expected levels, however appropriate limits will need to be confirmed with the EA following monitoring during commissioning and operation.

The CO₂ Emergency relief vent will only be used during start-up of the CO₂ compressors, when CO₂ may not meet the onward transport and storage specification. In addition, venting may also occur during process upset scenarios, however through careful process control and management CO₂ venting will be minimised as far as is possible.

No monitoring of the CO₂ vent is proposed, other than recording times and duration of when venting occurs.

6.2.2 CO₂ Export Monitoring

As stated previously, the PCC plants are being designed to achieve a capture rate of approximately 95% for baseload operation. The CO₂ for export will be required to meet the design specification of the onward transport and storage system, and therefore monitoring will be in place to ensure that this is the case.

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

- CO₂ quality.

As well as ensuring compliance with the pipeline specifications, it is also a requirement of the PCC BAT Guidance that these parameters are monitored.

6.3 Emissions to Water

Uncontaminated surface water run-off and clean wastewater from the process areas in the PCC plants will be collected, via an oily water separator, into a new holding pond (M4) located within the PCC plant area. The new M4 holding pond will release via a Class 1 oily water separator to the South Killingholme Drain via a new Emission Point W2, located in the southeast corner of the Extended Installation boundary (Appendix A, Figure 3).

The discharge rate from the new holding pond will be controlled to the greenfield runoff rate, calculated in accordance with the procedures described at www.uksuds.com, with a maximum daily effluent flow of 3,000m³/ day.

Monitoring of discharge volumes and flow-proportional sampling will be provided to ensure that discharges meet the proposed limits.

Table S3.2 of the existing Environmental Permit provides the emission parameters and associated emission limits and monitoring requirements for the site process effluent and surface water drainage. It is proposed that Table S3.2 is revised to include the new Emission Point W2 and the proposed limits to be applied to the W2 discharge are summarised below in Table 6.2, based on the uncontaminated nature of this discharge. Although the discharge is considered to be uncontaminated, it is proposed that a limit on COD is included in the permit, inline with the BAT-AEL provided in the LCP BATc and with the existing W1 monitoring already carried out at the Installation.

Table 6.2: Proposed Addition to Table S3.2 - Point Source Emissions to Water (other than sewer) - emission limits and monitoring requirements

Release Point	Parameter	Source	Proposed Emission Limit	Reference Period	Monitoring Frequency	Monitoring Standard
W2 Discharge to South Killingholme drain [NGR 517130 417000]	Flow	Site surface water drainage	3,000m ³ per day	-	Continuous	As agreed in writing with the EA
	pH		6.5 – 8.5 ¹	-	Continuous	As agreed in writing with the EA
	Temperature		30°C	-	Continuous	As agreed in writing with the EA
	Oil		5 mg/l	-	Weekly	As agreed in writing with the EA
	COD		150 mg/l		Weekly	As agreed in writing with the EA

Notes:

¹ A target for typical operation, but not subject to notification requirements. This is in line with the existing Environmental Permit.

7. Environmental Risk Assessment (Impact Assessment)

7.1 Introduction

This section discusses the potential impact on sensitive receptors and the surrounding area and shows how the emissions from the PCC plants have been assessed and minimised. Guidance contained in the EA guidance – ‘Risk assessments for your environmental permit’⁶, has been used to scope and assess the emissions from the PCC plants.

Where necessary baseline impact assessments and dispersion modelling has been completed to ensure that any predicted significant effects on sensitive receptors can be avoided/ mitigated.

The impact assessments are reported in the relevant Appendices of this Main Supporting Document:

- Air Quality Impact Assessment (Appendix F);
- CO₂ Modelling (Appendix H); and
- Noise Impact Assessment (Appendix I).

7.2 Installation Location and Sensitive Receptors

7.2.1 Human Receptors

The closest residential receptor to the Installation is a single residence along Marsh Lane, Hazel Dene, approximately 330m to the east of the Installation.

The receptors are selected to be representative of residential dwellings and recreational areas around the Installation and are shown in Table 7.1.

Table 7.1: Human Receptor Locations for Air Quality Assessment

I.D	Receptor	NGR Grid Reference	Approximate Distance and Direction from Installation
R1	Hazel Dene, Marsh Lane	517330, 417311	330m east
R2 ¹	Station House, Station Road	517333, 418345	1.1km northeast
R3	Fairfield House, North Garth	514687, 418769	2.4km northwest
R4	Old Vicarage, North Garth	514428, 418197	2.3km northwest
R5	Manor Farm, North Killingholme	514515, 417653	1km northwest
R6	Church Lane, North Killingholme	514763, 417331	1.5km west
R7	Westfield Farm, North Killingholme	514708, 416785	1.7km west
R8	Melrose, South Killingholme	515115, 416417	1.4km southwest
R9	Town St/ Humber Road, South Killingholme	515516, 416120	1.3km southwest
R10	South Killingholme Primary School	514880, 416120	2km west
R11	East End Farm	515935, 415730	1.1km south
R12	Immingham	517765, 415255	1.7km south

¹ R2 is currently understood to be an unoccupied residence owned by Able Humber Ports Limited, which is proposed to be demolished as part of Able Marine Energy Park enabling works

⁶ Risk Assessments for your Environmental Permit, DEFRA and EA, Published on: 1st February 2016, Last updated on: 31st August 2022, accessed at: <https://www.gov.uk/guidance/risk-assessments-for-your-environmental-permit>

7.2.2 Ecological Receptors

EA guidance requires that the effects of stack emissions on designated ecological sites be assessed where they fall within set distances of the source, up to 10km (or 15km for large emitters) for European designated sites and up to 2km for nationally designated sites.

Statutory designated sites have been identified through a desk study of the Defra Magic mapping⁷ website, which identifies Sites of Special Scientific Interest (SSSIs), Ramsar sites, Special Protection Areas (SPAs) and Special Areas for Conservation (SACs). In addition, non-statutory designated receptors have also been identified, including Local Wildlife Sites (LWSs) and Sites of Importance for Nature Conservation (SINC).

The relevant sites are listed below in Table 7.2.

Table 7.2: Ecological Receptor Locations in the Vicinity of the Installation

I.D	Receptor	Designation	NGR Grid Reference	Approximate Distance and Direction from Installation
E1	Humber Estuary	SAC, SPA, Ramsar, SSSI	517235 - 419385 - 517868 418379	1.3m north-east
E2	North Killingholme Haven Pits	SSSI	516875 419530	2.2km north
E3	Swallow Wold	SSSI	516950 404990	11.7km south
E4	Wrawby Moor	SSSI	503350 411120	14.5km southwest
E5	Eastfield Road Railway Embankment	LWS	515313 417108	1km west
E6	Burkinshaws Covert	LWS	516432 417874	700m north
E7	Rosper Road Pools	LWS	517224 416937	100m east
E8	Chase Hill Wood	LWS	515702 418875	1.9km north
E9	Mayflower Wood Meadow	LWS	516000 415920	1.2m southeast
E10	Homestead Park Pond	LWS/ SINC	517935 415625	1.5km southeast
E11	Eastfield Road Pit	SINC	515350 417040	1km west

There are three additional SSSI within 15km of the Installation (Kirmington Pits, Kelsey Hill Gravel Pits and South Ferriby Chalk Pit) which are designated due to their geological features. It is therefore considered that these sites will not be affected by emissions from the Installation, as the Critical Levels and Critical Loads assigned to such sites are for the protection of vegetation and ecosystems only, and therefore they have been screened from further assessment.

In addition, it is understood that the Station Road Fields LWS that was located 500m east of the Installation, has been lost due to the Able Marine Energy Park (AMEP) development.

7.2.3 Geology

As the existing Installation Site is already covered under the existing Environmental Permit, only details of the additional land proposed to be added to the Installation Boundary for the PCC plants has been covered in these sections.

Most of the additional land proposed to be added to the Installation Site Boundary (undeveloped land to the south of the existing Immingham CHP Power Plant), apart from a small area in the south and a small area adjacent to the southern boundary, comprises Tidal Flat Deposits consisting of Clay and Silt.

⁷ Defra Magic mapping accessed at <http://magic.defra.gov.uk/MagicMap.aspx>

The remaining area of the PCC plant area is shown as having superficial deposits of Till, Devensian – Diamicton

The bedrock across the entire PCC plant area consists of Burnham Chalk Formation.

7.2.4 Hydrology

The EA's Catchment Data Explorer indicates the PCC plant area is located within the North Beck Drain Water Body catchment. The current (2019) classification has a 'Moderate' ecological status and a chemical status of 'Fail' due to priority hazardous substances Mercury and its Compounds and Polybrominated Diphenyl Ethers (PBDE). This is also designated as a heavily modified water body.

The Envirocheck Report indicates there are eighteen OS Water Network Lines within the PCC plant area boundary which all are designated as inland rivers. Of the 18 inland rivers, 14 are located on the ground surface and four are located underground.

The Humber Estuary is located approximately 1.6km east of the PCC plant area.

The Envirocheck Report suggests the entire PCC plant area has the potential to be affected by river and coastal flooding where there are no defences. Areas in the east of the PCC plant area have been identified as potential areas affected by extreme river or coastal flooding without defences.

The risk of surface water flooding identified within the Envirocheck Report suggests there is a High Risk (30-year return period) associated with the drain that is located within the centre of the PCC plant area, orientated northeast to southwest, and a small area in the southeast near the PCC plant area. Areas within the centre and south of the eastern half of the PCC plant area are at Low Risk (1,000-year return period) of surface water flooding, although there are small areas in the southeast that are of Medium Risk (100-year return period). There are no surface water abstractions on the PCC plant area. There are two surface water abstractions operated by Immingham Town Council 1.5km southeast from the PCC plant area and one surface water abstraction operated by Drax Biomass (Immingham) Limited 1.9km northeast of the PCC plant area.

7.2.5 Hydrogeology

The superficial Tidal Flat deposits (Clay and Silt) are classified as an Unproductive Aquifer.

The superficial Devensian Till (Diamicton) deposits are classified as a Secondary Undifferentiated Aquifer. The EA defines a Secondary Undifferentiated Aquifer as *"where it is not possible to apply either a Secondary A or B definition because of the variable characteristics of the rock type. These have only a minor value"*.

The Burnham Chalk Formation underlying the Devensian Till (Diamicton) deposits is classified as a Principal Aquifer. The EA defines a Principal Aquifer as an aquifer that can *"provide significant quantities of drinking water, and water for business needs. They may also support rivers, lakes and wetlands"*.

The superficial Tidal Flat deposits (Clay and Silt) are classified as an Unproductive Aquifer. The Environment Agency (EA) defines an Unproductive Aquifer as *"largely unable to provide usable water supplies and are unlikely to have surface water and wetland ecosystems dependent on them"*.

The superficial Devensian Till (Diamicton) deposits are classified as a Secondary Undifferentiated Aquifer. The EA defines a Secondary Undifferentiated Aquifer as *"where it is not possible to apply either a Secondary A or B definition because of the variable characteristics of the rock type. These have only a minor value"*.

The Burnham Chalk Formation underlying the Devensian Till (Diamicton) deposits is classified as a Principal Aquifer. The EA defines a Principal Aquifer as an aquifer that can *"provide significant quantities of drinking water, and water for business needs. They may also support rivers, lakes and wetlands"*.

The Envirocheck Report (285387654_1_1) indicates the Principal Bedrock Aquifer within the Burnham Chalk Formation has a combined vulnerability of Low in the areas where it is underlain by the Tidal Flat deposits (Clay and Silt). This is due to the combination of a productive bedrock aquifer and an unproductive superficial aquifer associated with the Tidal Flat deposits (Clay and Silt). The EA describe Low vulnerability as *"areas that provide the greatest protection to groundwater from pollution. They are likely to be characterised by low leaching soils and/or the presence of low permeability superficial"*

deposits" (31). The 1:100,000 Groundwater Vulnerability Map on Magic Maps also suggests this area has a Low vulnerability.

The Secondary Undifferentiated Aquifer within the Devensian Till (Diamicton) deposits has a vulnerability of Medium in the northern third of the PCC plant area as well as in a small part of the south-western boundary of the PCC plant area. The remainder of the aquifer is classified as low groundwater vulnerability. This is due to the combination of a productive bedrock rock aquifer and a productive superficial aquifer. The EA describe Medium vulnerability as *"areas that offer some groundwater protection. Intermediate between high and low vulnerability"*.

A thin strip within the aquifer in the south-eastern boundary of the PCC plant area has a vulnerability of Medium-High due to the combination of the productive bedrock aquifer and a productive superficial aquifer. The EA describe High vulnerability as *"areas able to easily transmit pollution to groundwater. They are characterised by high leaching soils and the absence of low permeability superficial deposits"*. The 1:100,000 Groundwater Vulnerability Map on Magic Maps suggests this area has a Medium – High vulnerability.

The BGS Flood Data for groundwater flooding indicates that there is potential for groundwater flooding to occur in areas of the PCC plant area that are not overlain by the superficial Tidal Flat Deposits (Clay and Silt). There is potential for groundwater flooding at the surface on a thin strip within the PCC plant area.

The Envirocheck Report indicates there are no groundwater abstractions located within the Extended Installation Site Boundary. There are 19 groundwater abstractions within 1km of the PCC Plant area and there are a further 13 groundwater abstractions between 1km and 2km of the PCC Plant area.

The Envirocheck Report (285387654_1_1) indicates the entire PCC plant area is within an area classified as a Source Protection Zone (SPZ) SPZ3 (total catchment) and is associated with an SPZ1 located approximately 1km southeast from the PCC Plant area and an SPZ1 located within 5km of northwest from the PCC Plant area. The EA defines an SPZ3 as *"the area around a supply source within which all the groundwater ends up at the abstraction point. This is the point from where the water is taken. This could extend some distance from the source point"*. This may be associated with extensive industrial, commercial and public services groundwater abstraction and private water undertaking (raw water supply) groundwater abstraction located within 2km southeast of the PCC plant area.

7.3 Pathways for Pollution

In order for a pollution risk to occur, there has to be a source - pathway - receptor (S-P-R) linkage.

Pathways to sensitive receptors primarily include, but are not limited to, the following:

- chemicals required for the operation of the PCC plant could be accidentally released and leach into the ground and be washed into surface water or groundwater through the underlying soils.
- chemicals required for the operation of the PCC plants could be accidentally released and discharged into surface water via Emission Point at W2.
- flue gases from the PCC plants will be dispersed in the air to sensitive receptors.

In order to prevent and minimise the risk of pollution, the PCC plants will be designed and managed to isolate or reduce the effectiveness of these pathways, preventing contaminants from migrating off site other than through properly managed abatement systems.

The detailed description provided in Section 4 of this supporting document demonstrates how BAT have been applied to prevent pollution from the PCC plant.

7.4 Impact Assessment

The following sections provide an assessment of the impact of releases from the PCC plants, so as to underpin and justify the measures that will be put in place for their control and that will adequately protect the environment.

The risk assessment approach has been based on the following four sequential stages:

- identify risks from the activity;
- assess the risks and check that they are acceptable;
- justify appropriate measures to control the risks, if necessary; and
- present the assessment as detailed in the EA's Guidance 'Risk assessments for your environmental permit'.

Activities with the potential to impact on the surrounding environment have been identified in line with guidance provided by the EA, and include the following assessments:

- amenity and accidents;
- emissions to air;
- emissions to surface water;
- site waste;
- global warming potential; and
- site closure.

7.4.1 Amenity and Accidents

A qualitative risk assessment has been undertaken for the PCC plants activities and is included in Appendix K of this document.

A short description of the key potential risks from the PCC plants is provided in the following subsections.

7.4.1.1 Odour

Storage of amines for use in the PCC plants may have the potential to generate odour. The Cansolv D-103 solvent is considered to be a very low odour risk, due to its very low volatility, as detailed in Section 4.4.5.

Through the detailed design studies, potential for odour to result during the operation of the PCC plants will be considered, and appropriate measures will be implemented to prevent this.

7.4.1.2 Noise and Vibration

An assessment of operational noise and vibration from the PCC plants is provided in the Noise Impact Assessment (Appendix I).

The assessment of operational sound levels has been based upon a number of worst case assumptions, due to the early stage of design and calculations taking account of proposed plant and equipment sound power levels (L_w) relating to the proposed plant, distance between the proposed plant and Noise Sensitive Receptors (NSR) and the acoustic screening offered by existing topography and existing and proposed new buildings.

There is only one NSR likely to be impacted by noise from the PCC plants, that being a single residential dwelling on Marsh Lane (Hazel Dene).

Three-dimensional noise propagation models have been developed using the noise modelling software SoundPlan Version 8.2 to assess the current layout options for the PCC plants. SoundPlan implements the noise prediction method ISO 9613-2: 1996 'Attenuation of sound during propagation outdoors' (ISO, 1996), which has been employed to calculate sound levels at the NSR due to the operation of the PCC plant.

Topographical features and buildings that may influence the transmission of sound to the NSR are included in the noise model. A digital terrain model created using publicly available ground elevation spot height data have been used to position buildings and other noise sources at the proposed heights relative to ground. Areas of acoustically soft (e.g. vegetation) and hard (e.g. concrete) ground have been identified from the Ordnance Survey MasterMap Topographic Layer and modelled accordingly.

The prediction method assumes that the prevailing wind direction is always from source to receiver, which will overestimate the noise effects associated with the PCC plants.

Based upon the predicted sound levels from the noise model, an assessment of potential noise impact at the NSR has been undertaken using the guidance in BS 4142:2014+A1:2019 'Methods for rating and assessing industrial and commercial sound' (BSI, 2014c).

The assessment identifies that the noise rating level of the future operation would be less than 5dB(A) above the defined background sound levels, i.e. below the level at which adverse effects may occur. The resulting significance of impact in accordance with BS 4142 has been determined as either 'low impact' or up to 'adverse impact' before context considerations. VPI are already a continuously operating industrial source in the study area, and there are other industrial/ commercial activities in the area, therefore it is likely that residents at all NSR are already accustomed to industrial noise sources.

Additionally, the context discussion considers the predicted specific sound levels in relation to the relevant WHO Guidance⁸ indoors and outdoors and the more recent Night Noise Guidelines. It is concluded that the existing Installation and the proposed PCC plant is predicted to meet with the WHO limits externally.

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

A review of the potential mitigation measures and general BAT principles to achieve reductions in noise impacts has been carried out and their applicability to the Installation is detailed in Table 7.3.

Table 7.3: Best Available Techniques for Noise Mitigation and their Applicability

Technique	Description	Applicability
Operational Measures	<p>This include:</p> <ul style="list-style-type: none"> • Inspection and maintenance of equipment • Closing of doors and windows of buildings and enclosed areas, where possible • Plant operated by experienced staff • Avoidance of noisy activities at night, if possible 	These are part of good working practices at the Installation.
Low-noise equipment	Select low noise equipment where possible	When equipment is new or being replaced. Where practicable low noise equipment will be procured for the PCC plant.
Noise Attenuation	<p>This include:</p> <ul style="list-style-type: none"> • Use of screening or bunding to shield receptors from noise sources • Reducing the breakout noise from plant through the use of enhanced enclosures, or potentially containing them within a building • Screening or enclosing the compressors or other equipment 	Consideration of screening where required and the layout of the PCC plant has incorporated consideration for the potential of noise impact to occur, within the constraints of the plot plan.
Noise Control Equipment	<p>This includes:</p> <ul style="list-style-type: none"> • Reducing air inlet noise emissions by the addition of further in-line attenuation • Reducing stack outlet noise emissions by the addition of silencers or sound proofing panels • Reducing fin fan cooler noise emissions by screening, re-sizing, fitting low noise fans or attenuation • Use of anti-vibration supports and interconnections for equipment 	To be considered during the during the detailed design of the PCC plant.

⁸ WHO. (1999). Guidelines for Community Noise

Technique	Description	Applicability
Appropriate Location of Equipment and buildings	Orientation of plant within the Site to provide screening of low-level noise sources by other buildings and structures, or orientating fans and the air inlets away from sensitive receptors	This is generally applicable to new plant and has been considered during the development of the proposed PCC plant and will continue to be considered during the detailed design.

Specific measures to be applied for mitigating noise emissions will be confirmed during the detailed design phase, and be provided to the EA for approval prior to commencement of operations.

7.4.1.3 Fugitive Emissions

Based on the various controls placed on the site plant and equipment, it is expected that fugitive emissions from the PCC plants, particularly process emissions to air and water will be negligible.

7.4.1.4 Visible Plumes

Air-based cooling systems are being used for the PCC plants, which would integrate cooling for GT1 and GT2 and the PCC plants. Air cooling systems do not produce any steam and therefore the likelihood of their producing visible plumes is negligible.

The Air Quality Impact Assessment (Appendix F, Annex D) includes a plume visibility assessment for the PCC plant absorber stacks.

Visible plumes are predicted to occur for up to 85% of the time, with average plumes being up to 123m long.

7.4.1.5 Accidents

A Major Accident and Disasters assessment has been carried out for the ES (Appendix B (see Volume I, Chapter 16)), which details the main hazards for the PCC plants and identifies appropriate precautionary actions, to prevent or mitigate potentially significant risks associated.

For the management of day-to-day accidents, an Accident Management Plan (AMP) is in place for the Installation and will be amended to include the PCC plants including all associated equipment. 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:

- plans to deal with accidental pollution and any necessary equipment (e.g. spill kits) will be held in the PCC plant area and all site personnel will be trained in their use. The EMS incorporate details on how to appropriately deal with accidental spillages to ensure they are not released into any surface water system;
- implementation of containment measures, including bunding for bulk storage tanks. All chemicals will be stored in accordance with their COSHH guidelines;
- incorporation of interceptors into the drainage system to prevent spilled fuel 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 off-site if contaminated.

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:

- set-up and implementation of a specific preventive maintenance plan for these relevant systems;
- review and recording of emissions caused by OTNOC and associated circumstances and implementation of corrective actions if necessary; and
- periodic assessment of the overall emissions during OTNOC (e.g. frequency of events, duration, emissions quantification/ estimation) and implementation of corrective actions if necessary.

The management system will be amended to include the PCC plants prior to commencement of operations.

7.4.1.6 Flood Risk Assessment

A copy of the Flood Risk Assessment (FRA) undertaken for the Environmental Statement for the PCC plants Proposed Development is included in the ES (Appendix B (see Volume II, Appendix 9A)).

The FRA details that the PCC plant area is located in Flood Zone 3, land assessed as having a greater than 1% AEP (1 in 100-year return period).

As part of the development of the FRA, the EA has confirmed that tidal defences, consisting of earth embankments and concrete floodwalls protect the Installation. The EA owns, inspects and maintains these defences and advises that the defences are in fair condition and reduce the risk of flooding (at the defence) up to the 0.5% AEP (1 in 200-year return period) flood event.

The EA has provided breach location and associated breach hazard map, which is detailed in the FRA. Although a breach of flood defences would represent a significant hazard, the likelihood of breach is low, however the National Planning Policy Framework still requires plans and mitigation to be put in place to manage the risks should a tidal breach occur.

The risk of fluvial flooding for the Installation is considered to be low, given that the site is not located in proximity to any main rivers. There is a residual risk of flooding from ordinary watercourses in the event that they become tide-locked.

The following mitigation measures are considered appropriate to protect the PCC plant area, in accordance with the legislative and regulatory authority requirements:

- It is impractical to raise all equipment above the highest possible flood level therefore finished floor levels for the VPI Site will not be raised above the highest possible flood level and will remain below the 2115 0.5% AEP breach water level. In line with EA guidance flood resistant and resilient measures will be incorporated into the building design;
 - pipelines and storage tanks designed to withstand the water pressures associated with high return period event flooding;
 - tanks securely tethered in such a way to ensure the infrastructure remains secure should flooding occur;
 - electrical supply entering from height and down to required connections;
 - use of flood barriers on access points;
 - protecting wiring for operational control of the PCC plant, telephone, internet and other services by suitable insulation in the distribution ducts to prevent damage;
 - materials with low permeability up to 0.3 m and accept water passage through building at higher water depths;
 - flood proofing including the use of flood resistant building materials, use of water resistant coatings, use of galvanised and stainless steel fixings and raising electrical sockets and switches;
 - utilising floor materials that are able to withstand exposure to floodwater without significant deterioration and that can be easily cleaned, e.g. concrete-based or stone;
 - incorporating water resistant services within the buildings, i.e. avoid services using ferrous materials;
 - design development to drain water away after flooding;
 - provide access to all spaces to permit drying and cleaning;
 - carefully considering the usage and layout of ground floor areas to minimise the potential impact on business operations following a flood;
 - suitable waterproofing measures to development located below ground i.e. tanking below ground storage areas etc.
 - development defined as critical infrastructure will be located at existing ground level for operational reasons therefore flood resilience and resistance measures will be put in place

(e.g. raised plinths, watertight housing bunding where practicable etc), as with other critical infrastructure within the wider Installation; and

- preparation of a Flood Emergency Response Plan, and Emergency access and egress. Safe refuge will be provided within the existing Installation. This will allow any individuals on the Site to wait safely until the flooding subsides or rescue can be affected.

7.4.2 Emissions to Air

An air dispersion modelling exercise has been undertaken to:

- Assess the impact on local air quality as a result of the anticipated emissions identified Table 5.1 above.
- Confirm the heights of the exhaust stacks so as to ensure adequate dispersion for the PCC plant Absorber stacks and therefore ensure acceptable impacts at receptors.

A copy of the Air Quality Impact Assessment is included in Appendix F and the key findings are summarised below.

7.4.2.1 Impact on Local Air Quality

The existing combustion emissions from GT1, GT2 (NO_x and CO) and the two Aux Boilers (NO_x, CO, SO₂ and particulates) are currently released to air via 90m high dedicated flues. These emissions will continue to be released from the two stacks on top of the PCC plant Absorber column, at a height of 110m. The additional stack height is required to improve dispersion due to the lower temperature of the release from the absorber columns compared to the existing release points. There will also be additional emissions of amines and their degradation products, as a result of the operation of the PCC plants.

Detailed dispersion modelling has been used to calculate the Process Contributions (PCs) of pollutants at identified sensitive receptors and these have been compared with National Air Quality Strategy (NAQS) objectives and Environmental Assessment Levels (EALs) for human health receptors, and Critical Levels and Critical Loads for ecosystems, with consideration of the baseline air quality and ecological deposition rates, in accordance with the EA Risk Assessment guidance.

The assessment compares the predicted impacts of the future operation of the PCCs plant under normal operating conditions (i.e. GT1, GT2 and the two Aux Boilers exhaust gases being abated by the PCC plants, operating for up to 8,760 hours per year), to the current unabated operation of the units to the existing Emission Points A1 – A4.

7.4.2.2 Detailed Dispersion Modelling Results

The maximum process contributions (PCs) of all species released (except annual average and hourly NO₂) can be screened as having 'insignificant' impacts at human health receptors by the dispersion modelling, at the first stage of screening, being either below the 10% threshold for short-term impacts, or 1% threshold for annual mean impacts for the future operation.

Annual average NO₂ can be screened from further assessment at the second stage of screening, as the predicted environmental concentration (PEC) is less than 70% of the NAQS. Hourly impacts represent only 31% of the respective NAQS objective and therefore indicate that no exceedances are likely to occur.

The assessment of impacts at human health receptors has also considered the impact of emissions of N-amines degradation products from the PCC plants. This assessment considers both the direct release of N-amines from the PCC plant, as a result of solvent degradation within the process, and also the subsequent atmospheric degradation of the amines released from the stack.

Although there is large uncertainty in the modelling methodology for the atmospheric degradation of amines, the modelling assessment carried out takes into account worst-case assumptions and shows that an exceedance of the AQAL is very unlikely as a result of the operation of the PCC plants.

The impacts at ecological receptors have also been determined, and the assessment results show that while there is generally a slight increase in the predicted impacts at all receptors over the current unabated operation of the GT1, GT2 and Aux Boilers, these increases are considered to be insignificant, in that they are less than 1% of the Critical Levels for annual average increases.

Deposition impacts have also been assessed, and the full results are presented in Air Impact Assessment in Appendix F. Both the nutrient nitrogen and acid depositional impacts are insignificant (<1% of the relevant critical loads at the majority of ecological sites), and where this is not the case, the increase in impacts over the Baseline assessment is considered unlikely to adversely affect the ecological features present.

7.4.3 Emissions to Water

There will be discharges of uncontaminated process and surface waters to South Killingholme Drain via new Emission Point W2, as detailed in Section 5.2.1.2. Given the uncontaminated nature of these discharges no assessment of the emission to water is deemed to be required.

7.4.4 Site Waste

The details of anticipated waste streams generated by the PCC plants are provided in Section 4.9.

All operational waste will be dealt with in accordance with the existing Installation's waste management procedures, amended as required for the PCC plant operation, with appropriated designated storage areas for hazardous and non-hazardous wastes, and consigned via a registered waste carrier for treatment or disposal at a suitably licenced waste facility.

It is therefore considered that further assessment of the waste from the PCC plants operation is not required.

7.4.5 Global Warming Potential

This section is based on guidance presented in the EA guidance – 'Assess the impact of air emissions on global warming'⁹.

The PCC plants will be designed to capture of approximately 95% of the CO₂ emissions resulting from the existing operation of GT1, GT2 and the two auxiliary boilers. This equates to approximately 3,262,414 tonnes of CO₂ that would have been released into the environment being captured per year. Therefore, the global warming impact of the emissions to air from the Installation will be significantly reduced.

Additional energy (electricity and steam) is required to provide power and heat to the PCC plant, therefore there is an increase in release of greenhouse gas (GHG) emissions associated with the additional energy production.

Table 7.3 presents the additional energy requirements and resulting GHG emissions for the PCC plants. To show the reduction in annual CO₂ emissions as a result of the PCC plants installation, the effective CO₂ emission factor applied to the additional energy consumption would need to be a negative number; this would imply that as energy consumption increases, less GHG emissions would be released into atmosphere. This is clearly not the case and therefore the CO₂ emission factor and annual emissions cannot be provided. The emissions from the additional energy requirements have been captured within the operational emissions of the Proposed Development in the ES (Appendix B, Volume I, Chapter 14 Climate Change, Table 14.19).

Table 7.4: Additional Annual Energy Consumption for the PCC Plants

Energy Source	Energy Consumption Primary		
	At Primary Source	CO ₂ Emission Factor	Annual CO ₂ Emissions (tonnes)
CO ₂ Captured by PCC Plants	-	-	-3,262,414
Electricity & Steam supply	1,631,112MWh	N/A	N/A
Total CO₂ Reduction	-	-	N/A

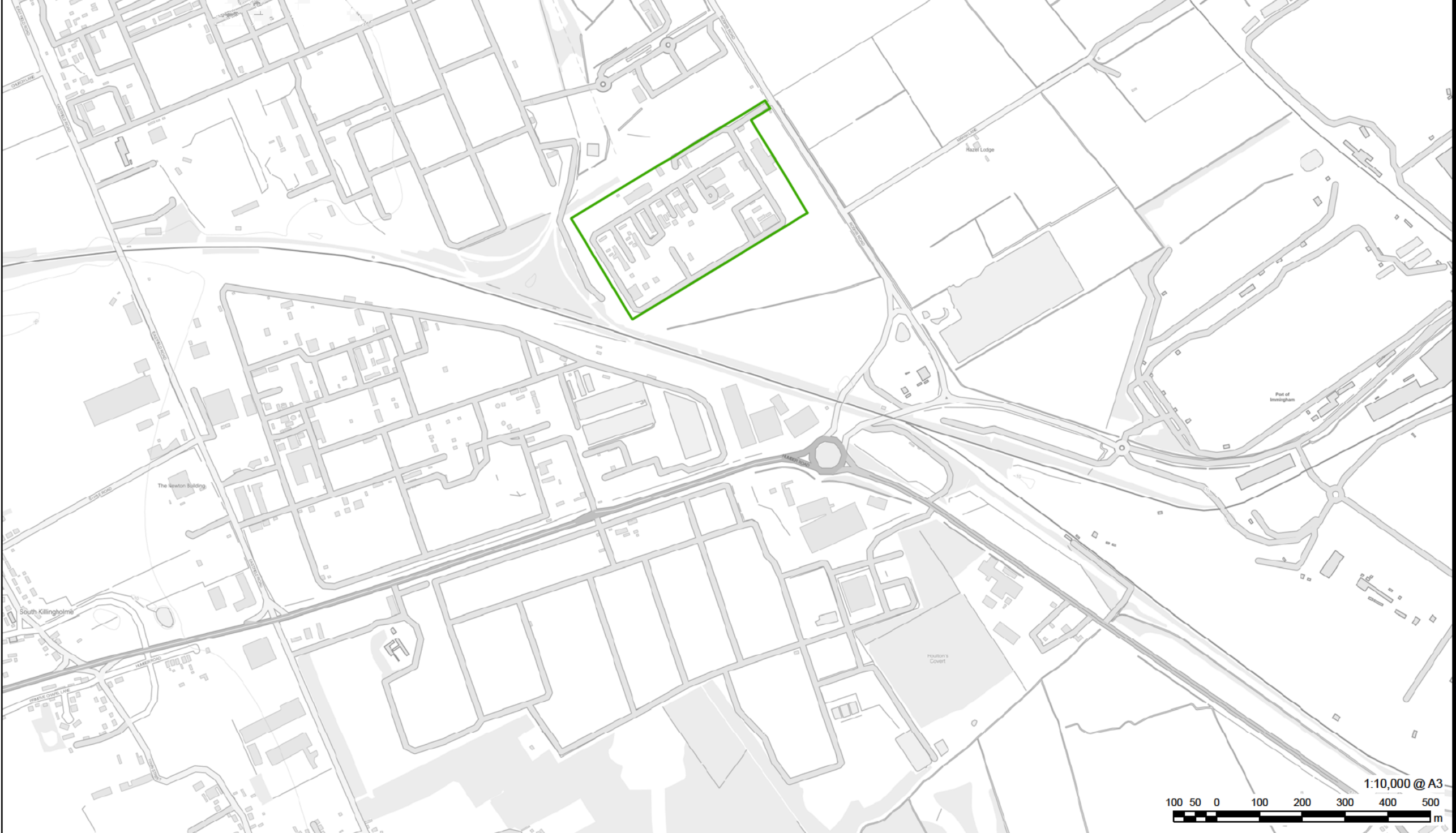
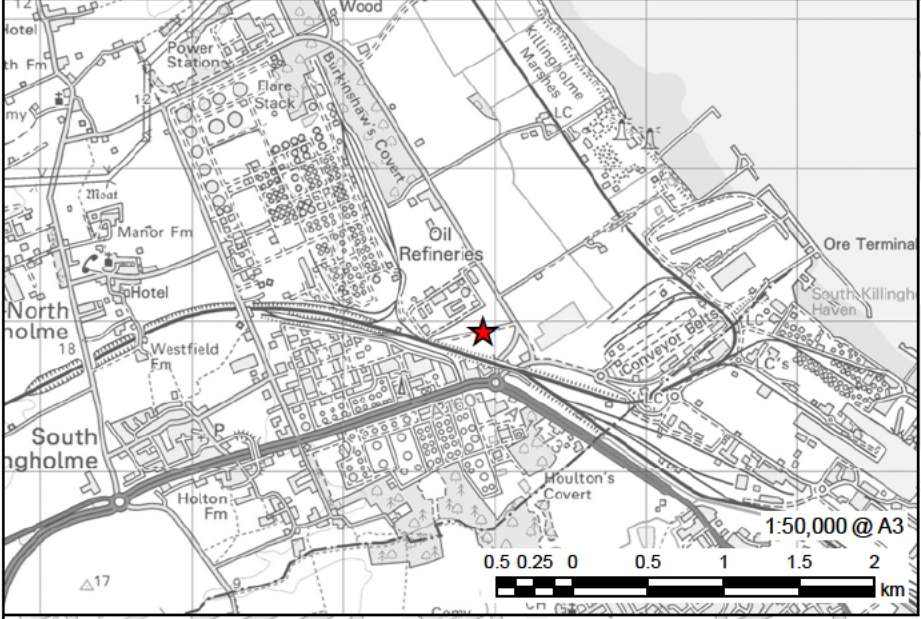
⁹ Assess the impact of air emissions on global warming, DEFRA and EA, published on: 1st February 2016, available at: <https://www.gov.uk/guidance/assess-the-impact-of-air-emissions-on-global-warming>

7.5 Site Closure

A plan for appropriate decommissioning and closure of the PCC plants at the end of their operating life will be developed. The plan will ensure that the Installation is returned to the baseline condition, as outlined in this application.

Appendix A - Figures

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PROJECT
Environmental Permit
Variation Application

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LEGEND
Existing Installation Site Boundary
Site Location

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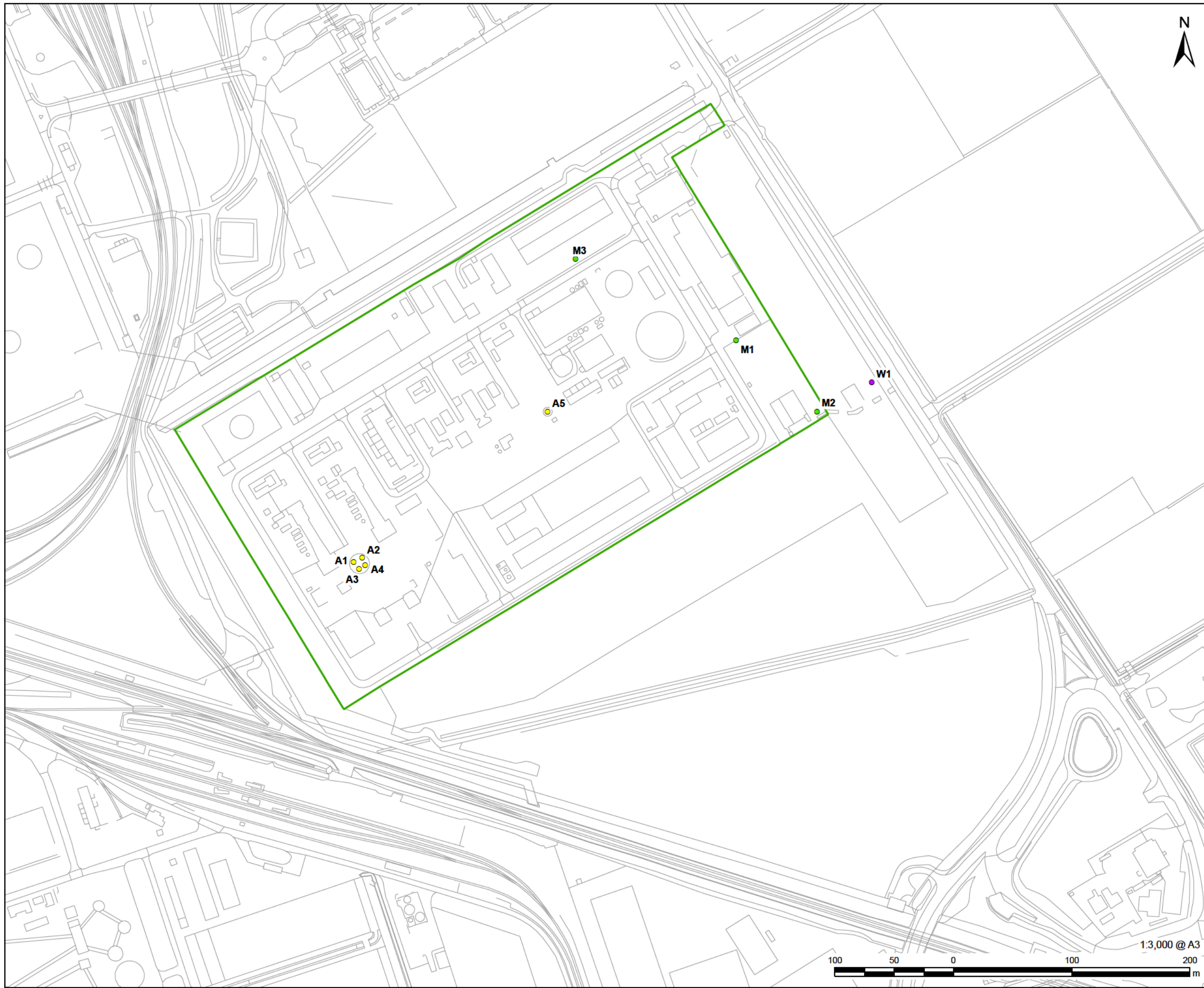
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PROJECT NUMBER
60668866

FIGURE TITLE
Site Location Plan

FIGURE NUMBER
Figure 1

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- LEGEND**
- Existing Installation Site Boundary
 - Emission Point to Air
 - Emission Point to Water
 - Holding Pond

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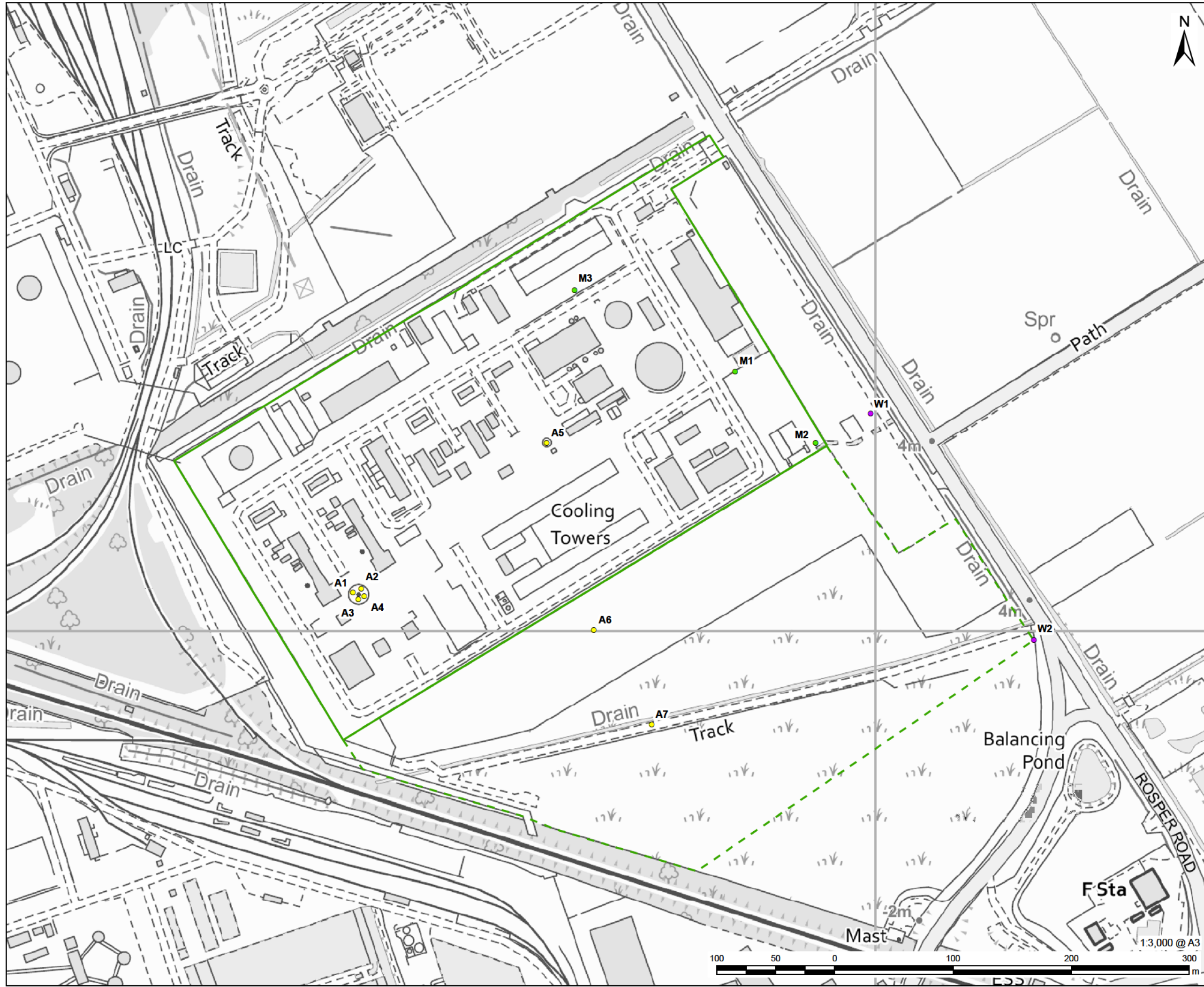
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FIGURE TITLE
Existing Installation
Site Boundary

FIGURE NUMBER
Figure 2



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LEGEND

- Existing Installation Site Boundary
- Indicative Extended Installation Boundary
- Emission Point to Air
- Emission Point to Water
- Holding Pond

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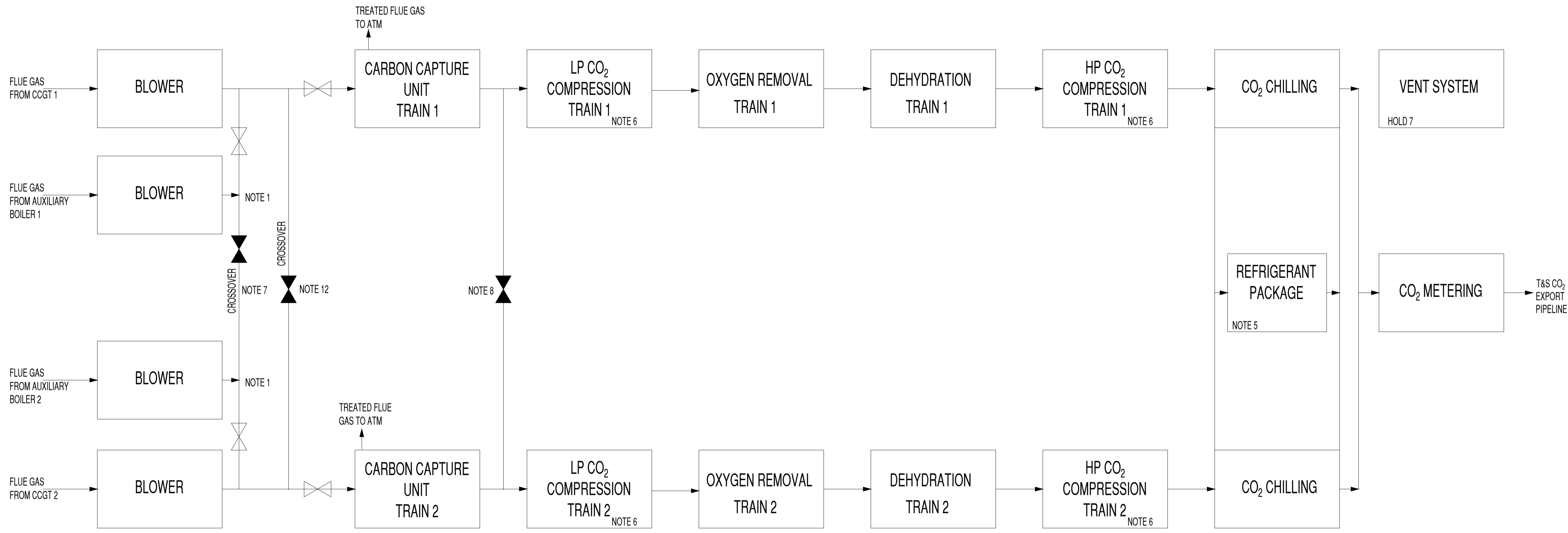
ISSUE PURPOSE
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PROJECT NUMBER
 60668866

FIGURE TITLE
 Installation Location

FIGURE NUMBER
 Figure 3

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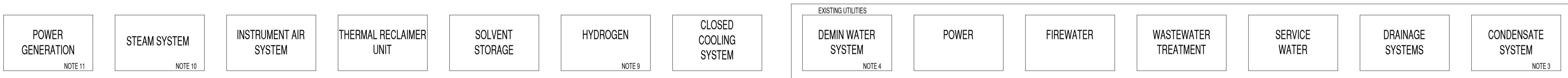


NOTES:-

1. AUXILIARY BOILER FLUE GAS DUCTING CO-MINGLING LOCATION SHALL BE DOWNSTREAM OF A BLOWER LOCATED WITHIN THE CCU TRAIN.
2. CCU REQUIRES LP AND MP STEAM. SOURCE OF STEAM SUPPLY TO BE CONFIRMED.
3. RETURN MP AND LP STEAM CONDENSATE TO VPI CHP VIA UTILITY SYSTEM (HOLD 8).
4. DEMIN WATER REQUIRED FOR INITIAL FILL AND THEREAFTER INTERMITTENTLY FOR FRESH SOLVENT DILUTION.
5. REFRIGERANT PACKAGE DETAILS TO BE CONFIRMED. REFRIGERANT IS REQUIRED TO COOL THE CO₂ TO 25°C.
6. LP AND HP STAGES ARE COMBINED IN ONE COMPRESSOR THERE WILL BE ONE COMPRESSOR PER TRAIN.
7. CROSSOVER LINE TO ENABLE FLUE GAS FROM AUXILIARY BOILER TO BE ROUTED TO EITHER TRAIN 1 OR TRAIN 2 (MANUAL ON/OFF SELECTION).
8. CROSSOVER LINE TO ENABLE CO₂ TO BE ROUTED TO EITHER LP COMPRESSOR TRAIN (MANUAL ON/OFF SELECTION).
9. HYDROGEN IS SUPPLIED TO REACT WITH OXYGEN IN THE OXYGEN REMOVAL REACTOR. IT IS INJECTED UPSTREAM OF THE 4TH STAGE OF THE LP COMPRESSOR TO FACILITATE MIXING.
10. STEAM DISTRIBUTED AS MP AND LP STEAM.
11. NEW STEAM TURBINE GENERATOR
12. CROSSOVER LINE TO ENABLE FLUE GAS AT THE CCU INLET (i.e. CCGT AND AUXILIARY BOILER FLUE GAS) TO BE ROUTED TO EITHER TRAIN 1 OR TRAIN 2.

HOLDS:-

1. (DELETED)
2. (DELETED)
3. (DELETED)
4. (DELETED)
5. (DELETED)
6. (DELETED)
7. CO₂ VENT TO STACK LOCATIONS TO BE IDENTIFIED.
8. (DELETED)
9. (DELETED)
10. (DELETED)
11. (DELETED)



REV	DATE	REVISION DESCRIPTION	DRAWN	DRAFT CHR	DESIGNED	ENG CHK	APPROVED	REF DRAWING No	REFERENCE DRAWING TITLE
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B	18/03/22	ISSUED FOR REVIEW	AG	MW	SR	CV			
A	25/02/22	ISSUED FOR SQUAD CHECK	MW		SR	CV			

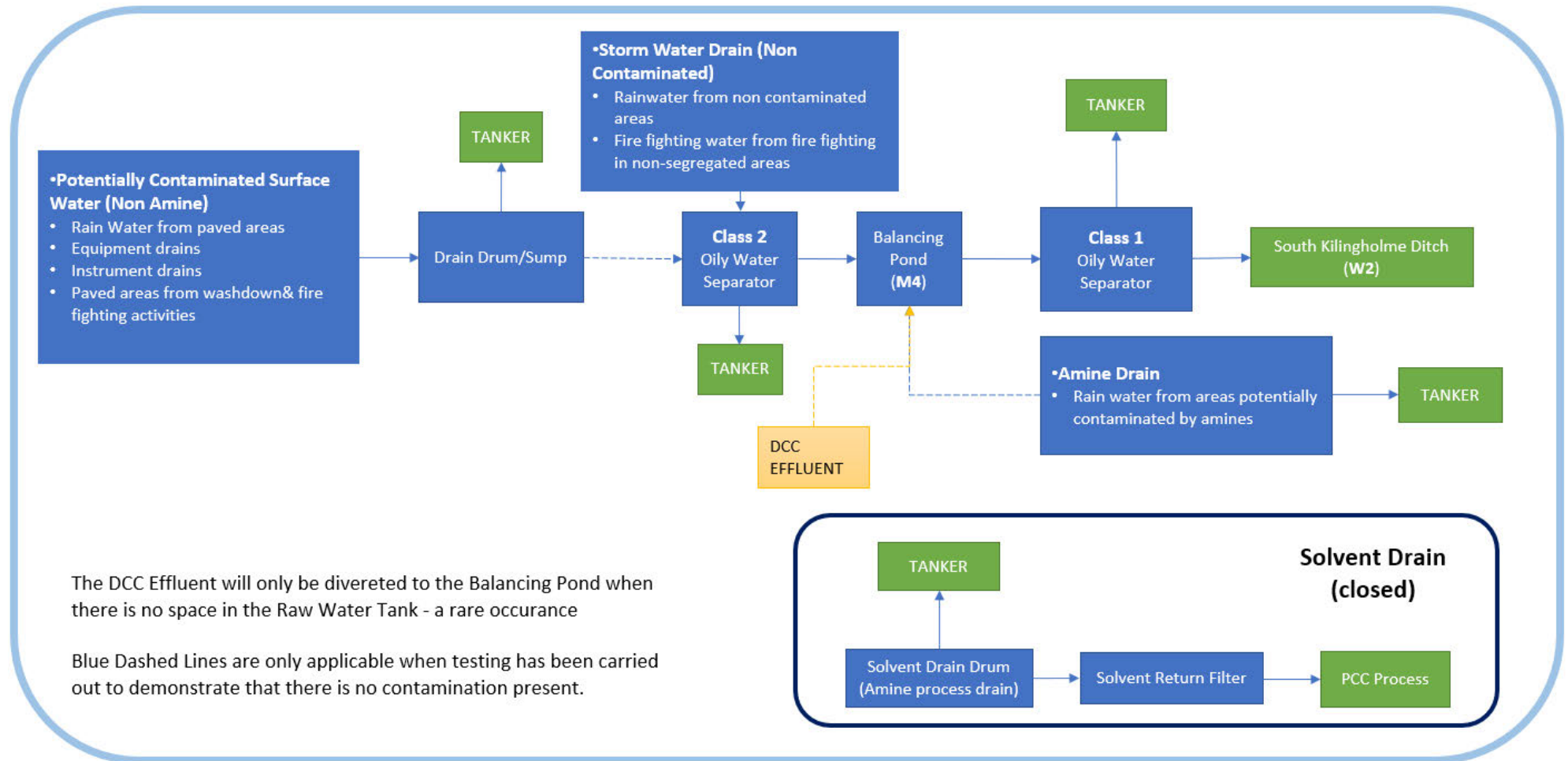
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WORLEY PROJECT No	415000-00201	

Worley
energy | chemicals | resources

VPI Immingham
HUMBERZERO

DRG TITLE	HZ VPI-I PCC PROJECT FEED BLOCK FLOW DIAGRAM	
DRG No	415000-00201-8100-20-0001	REV 0

Figure 6 – Drainage Flow Diagram for the PCC Plant Area



Appendix B – Environmental Statement

See separate electronic folder.

Appendix C – Site Condition Report

See separate electronic folder.

Appendix D – PCC Indicative BAT Assessment

It should be noted that the EA Guidance does not have the same legal status as BRefs published under the IED, and indeed the webpage states that “*Except where stated, this BAT guidance is not a regulatory requirement but identifies important environmental issues to address and best practice*”.

<https://www.gov.uk/guidance/post-combustion-carbon-dioxide-capture-best-available-techniques-bat>

Ref.	BAT Requirement	Response
1. Power Plant Selection and Integration with the PCC Plant		
BAT for efficiency of fuel use in power and CHP plants with PCC		
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>Opportunities for maximising thermal energy efficiency will be explored and integrated in the design of the PCC plants. For instance, the air-cooled systems for the PCC plants are to include forced draft fans to minimise heat recirculation so as to reduce the overall cooling load.</p> <p>The fan motors will also have variable drives which will ensure the number of fans in operation is proportional to the cooling load.</p> <p>A major part of the process is the MVR which significantly reduces steam demand. Additional measures for maximising energy efficiency of the Immingham CHP Power Plant when fitted with PCC will be investigated during detailed design.</p>
	For natural gas power plants, lower heating value efficiencies of 60% or above without CO ₂ capture are reported in the LCP BRef to be achievable for large-scale new combined cycle gas turbine installations.	Not applicable as the PCC plants are retrofits to existing GTs and Aux Boilers.
Dispatchable Operation		
1.2	<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.</p> <p>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>	The Installation operates as a baseload plant, principally providing heat and power to the adjacent refineries. As such, dispatchable operation will be limited to ramping up and down in response to grid demand (i.e. flexible operation).
2. Supplying Heat and Power for PCC Operation		
2.1	<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>Initial estimates have been developed for heat and power requirements. These have been documented in specific FEED deliverables, including Heat and Material Balance, Electrical Load List and the Equipment List. These estimates are based on a project specific solvent.</p>
	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	All heat and electricity for the PCC plants will be provided by the existing Installation.

Ref.	BAT Requirement	Response
	<p>treated as a power plant system for performance calculations.</p> <p>Typically, the best heat supplied to lost power ratio will exceed 4:1 for regeneration heat supplied at 130°C. It follows that if you use electricity instead of steam in PCC heating, for example to compress the vapour produced from flashing lean amine so that it can be fed back into the amine stripper, you should aim to achieve a similar ratio. This will ensure that the overall impact on plant electricity output is no higher than for steam extraction.</p> <p>You will achieve the best use of any additional fuel inputs when as much electricity as possible is also generated from the energy in the fuel before supplying the low grade heat. You can assess this based on:</p> <ul style="list-style-type: none"> • the thermal efficiency of a BAT baseload-capable power plant without capture using that fuel • the ratio between heat supplied for PCC and the reduction in electrical power output from the relevant unabated BAT power plant output in the LCP BREF, which should exceed 4:1 for a typical amine regeneration heat supply at 130°C. 	<p>The existing CHP is configured to produce HP steam for the adjacent refineries. Retrofitting the Immingham CHP Power Plant to produce LP steam was considered but discounted due to technical challenges with implementation. To generate LP steam, HP steam will be let down via a new steam turbine generator. The generator will produce additional power for export/ onsite consumption whilst the LP steam will be used in the PCC plants</p> <p>In addition, the MVR scheme will result in a reduction in total energy demand compared to a scheme without MVR.</p>
3. PCC Plant Design and Operation – Purpose		
3.1	<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>The PCC plants have been designed to capture approximately 95% CO₂ in the flue gas treated.</p>
3.2	<p>You should capture CO₂ during start-up and shutdown as part of using BAT.</p>	<p>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 up to 1 hour to meet the required specification. As such CO₂ may be vented to atmosphere via the CO₂ Absorbers during this time.</p> <p>The start-up time is anticipated to be shorter than for new build CCGTs due to the availability of steam on Site which can be readily used to start the capture plant independent of the GTs</p> <p>As the Installation is a baseload plant however, it is anticipated that there will be limited start-ups per year.</p>
3.3	<p>You will need to deliver CO₂:</p> <ul style="list-style-type: none"> • at local transport system pressures (gas phase such as 35 bar or dense phase such as 100 bar) with levels of water, oxygen and other impurities as required for transport and storage such as that for the system operator National Grid (NGC/SP/PIP/25 Dec.2019) 	<p>The onsite conditioning system will remove oxygen and water from the CO₂ and compress to dense phase to meet the requirements of the T&S network. 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</p>

Ref.	BAT Requirement	Response
		<p>metering will be provided for custody transfer of CO₂ sent to the T&S network.</p> <p>Onward transport of the captured CO₂ will be undertaken by a separate operator after the onsite CO₂ metering station.</p>
3.4	<p>The PCC plant must also have acceptable environmental risks through preventing or minimising emissions, or render them harmless. You must achieve environmental quality standards for air emissions from the PCC plant and their subsequent atmospheric degradation products (including, for example, nitrosamines and nitramines). You should confirm this using:</p> <ul style="list-style-type: none"> atmospheric dispersion and reaction modelling tools specific site parameters which will define plant-specific ELVs 	<p>Dispersion modelling has been carried out to demonstrate that environmental quality standards for air emissions from the PCC plants and their subsequent atmospheric degradation products will not be exceeded as a result of the PCC plants' operation. The Air Impact Assessment is provided in Appendix F of this document.</p>
3.5	<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>The design has optimised power demand through the selection of efficient equipment, implementation of energy recovery scheme (MVR), and selection of an energy efficient capture technology.</p>
4. Solvent Selection		
4.1	<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 BAT review. There is particular concern about impacts on the environment from nitrosamines and other potentially harmful compounds formed by reaction of the amines and their degradation products with nitrogen oxides (NO_x) in the flue gases. 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 remove degradation products solvent formulations including secondary amines or other species that may have lower regeneration heat requirements may readily form nitrosamines with NO_x 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 project-specific potential for absorber stack emissions and consequent environmental impacts will depend on the selected solvent. You should assess your plant design and operation, plus local environmental factors, based on:</p> <ul style="list-style-type: none"> direct emissions of solvent components formation of additional substances in the PCC system and emissions of those substances formation of further additional substances in the atmosphere from emissions from the 	<p>The PCC plants will utilise the Cansolv DC-103 solvent, and the plants have been designed with the specific solvent and degradation characteristics in mind.</p> <p>The solvent regeneration and reclamation process will minimise solvent degradation, in order to minimise emissions and potential environmental impacts, as demonstrated in the Air Impact Assessment. This assessment has taken into account both the direct and indirect impacts of N-amines resulting from anticipated amine and N-amine releases.</p>

Ref.	BAT Requirement	Response
PCC system		
4.2	<p>The potential for solvent reclaiming and other cleaning methods is also an important factor in solvent selection. You should make sure it is practicable to remove all non-solvent constituents from the solvent inventory as fast as they are added during operation, to avoid accumulation. You should also make sure that you:</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 PCC plants will include solvent filtration units which will take a slip stream of the solvent from the absorber for continual cleaning. Most of the filtered solvent is routed to the Lean Solvent Coolers for reuse in the Absorbers, however a further slip stream of this will go to the Thermal Reclaimer, which will also operate continuously.</p> <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.</p> <p>Until operation commences it is not possible to confirm how much solvent can be reclaimed, although based on operating experience from plants utilising the same solvent, it is anticipated that > 99% of solvent will be reclaimed.</p> <p>In maximising solvent reuse on site, reclaimer wastes will be minimised as far as possible.</p>
4.3	<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) flue gases and power plant operating patterns over a period of at least 12 months.</p>	<p>Although a pilot plant trial has not been carried out on the VPI flue gases, the solvent provider has accumulated several thousand of hours of testing on various flue gases and commercial scale operation of the Cansolv D-103 solvent, including:</p> <ol style="list-style-type: none"> 1. 5,000 hours of pilot scale testing at Fortum Oslo Varme AS (FOV) (in July 2018) to demonstrate that the Shell's Cansolv capture technology using solvent DC-103 is suitable for cleaning CO₂ from the exhaust gases of waste to energy (WtE) plant at Klemetsrud in Oslo, Norway – solvent reclaiming was not performed as part of this test 2. 10 years operational experience at Brothers Chemical, South Africa. Commercial scale plant at 60,000 tonnes per annum processing gas boiler flue gas which is analogous to VPI's flue gas in composition. Batch reclaiming of solvent is typically performed every second month. 3. Over 6 years operating experience at SaskPower's Boundary Dam coal power plant. 1MTPA commercial scale plant – batch reclaiming of solvent is performed. 4. Planned test campaign at TCM (Commencing Q1 2023). Target 5 months testing on CHP and refinery FCC flue gases.
5. Flue Gas Cleaning		
5.1	<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>These products are typically stable under reclaimer conditions, but the heat stable salt</p>	<p>GT1 and GT2 are gas-fired plant, and therefore SO_x emissions are very low in this instance.</p> <p>When the Aux Boilers are fired on Refinery Off-gas there is potential for SO_x to be present in the flue gas, and therefore the DCCs will be dosed with caustic to remove SO_x prior to the flue gas being introduced to</p>

Ref.	BAT Requirement	Response
	<p>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 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>the PCC plants, to minimise the potential for SO_x to react with the amine solvent. Caustic will also be added to the Thermal Reclaimer to enable the separation of the amine solvent.</p>
5.2	<p>The impact of NO_x in the flue gas will vary significantly with the solvent composition. If the amine blend will form significant amounts of stable nitrosamines with NO_x in the flue gas, then you must reduce NO_x to as low a level as practicably possible using selective catalytic reduction (SCR).</p> <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 NO_x in the flue gas on atmospheric degradation reactions and this may also affect the need for SCR.</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>Based on the current NO₂ concentrations within the NO_x emissions from GT1, GT2 and the Aux Boilers it is not considered necessary to include SCR for NO_x reduction when using the Cansolv DC-103 solvent, as detailed in Section 4.2.2.</p> <p>No SCR proposed.</p> <p>Not applicable.</p>
5.3	<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. You should also carry out regular isokinetic sampling in the operational plant to assess total vapour and droplet emission levels.</p>	<p>SO₃ and fine particulates are not present in the VPI flue gas. However, a mist eliminator will be located after the water wash section at the top of the Absorber columns to minimise aerosol release. In addition, an antifoam skid will be installed to mitigate foaming.</p>
5.4	<p>You may need to remove materials in the flue gas that would accumulate as impurities in the solvent (such as metals, chlorine and fly ash) to lower concentrations than is required under the LCP BRef. This is to ensure satisfactory PCC plant operation. Whether you need to do this will depend on the specific solvent properties and the effectiveness of the solvent management equipment (such as filtering and reclaiming).</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>Not applicable</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 this application.</p>

6. PCC System Operation

Ref.	BAT Requirement	Response
Operating Temperatures		
6.1	<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 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>	<p>The PCC plant design is such that it will operate at optimised conditions for the Cansolv DC-103 solvent.</p>
Solvent Degradation		
6.2	<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>The PCC plant design is such that it will operate at optimised conditions for the Cansolv DC-103 solvent.</p>
7. Absorber Emissions Abatement		
Water Wash		
7.1	<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>There will be a single water wash section in place, which will enable solvent reuse.</p> <p>In addition, a mist eliminator will reduce aerosols present in the released flue gas.</p> <p>There is no SCR, therefore ammonia emissions will be minimal from the operational PCC plants, limited to any generated as an amine degradation product.</p>
Acid Wash		
7.2	<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 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"> • emission 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>An acid wash is not considered necessary to further reduce amine, ammonia or other pollutants from the process, based on the expected emission concentrations.</p>

Ref.	BAT Requirement	Response
Droplet Removal		
7.3	<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>A mist eliminator will be located at the top of water wash section to prevent the entrainment of droplets into the waste gases.</p>
Stack Height		
7.4	<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 used for flue gas reheating (see section 4 on cooling).</p>	<p>Detailed dispersion modelling has shown that a stack height of 110m for the PCC plants will result in no exceedance of any air quality standards for pollutants released.</p> <p>On the basis of the model results, it is not considered that flue gas reheating is required.</p>
8.0 Process and Emissions Monitoring		
Role of Monitoring		
8.1	<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>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>The Installation is already required to monitor and report energy and resource efficiency figures. The PCC plants operation will also be equipped with the capability to monitor continuously and to report the resource and energy efficiency of the plant.</p>
8.2	<p>It is 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>It is proposed that a monitoring plan will be produced prior to commissioning of the PCC plants, and therefore is it requested that this requirement be included in the Environmental Permit as a Pre-operational condition.</p>
8.3	<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 are managing the process to prevent (or minimise) the formation of solvent degradation products.</p>	<p>Monitoring will be carried out in line with proposals in Section 6.1 of this document.</p>
8.4	<p>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.</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>

Ref.	BAT Requirement	Response
9. Point Source Emissions to Air		
9.1	<p>You must include monitoring to demonstrate compliance with the with the IED Chapter III ELVs and the LCP BRef BAT-AELs at normalised conditions.</p> <hr/> <p>You must also monitoring for:</p> <ul style="list-style-type: none"> • Ammonia • Volatile components of the capture solvent • Likely degradation products such as nitrosamines and nitramines <hr/> <p>Your monitoring may be either:</p> <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>CEMS for monitoring of combustion gases from the PCC plants will be installed. In addition, the existing CEMS on the GT1, GT2 and Aux Boiler Emission Points A1 – A4 will be maintained for in the event that the Installation is required to operate in CO₂ unabated mode.</p> <hr/> <p>It is intended that CEMs monitoring of these species will be included for the PCC plants, however the exact specification of equipment to monitor the amines and degradation products is yet to be confirmed. If no suitable equipment is available, these will be monitored by periodic extractive monitoring.</p> <hr/> <p>As described above.</p>
9.2	<p>Emission sampling point must also comply with M1 sampling requirements for stack emission monitoring.</p>	<p>Emission sampling locations will comply with M1 guidance as far as is possible.</p>
10. Process Control Monitoring		
10.1	<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 • 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 	<p>The PCC plants 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 and maintain appropriate dilution ratio.</p>
Monitoring of CO₂		
10.2	<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 • CO₂ quality 	<p>These parameters will be monitored as part of the PCC plant operation.</p>
Monitoring Standards		
10.3	<p>The person who carries out your monitoring must be competent and work to recognised standards such as the Environment Agency's MCERTS scheme.</p> <p>MCERTS sets the monitoring standards you should meet. The Environment Agency recommends that you use the MCERTS scheme</p>	<p>Any extractive monitoring carried out on the emissions from the PCC plants will be carried out by MCERTS accredited contractors.</p>

Ref.	BAT Requirement	Response
	<p>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>	
	You must use a laboratory accredited by the UKAS to carry out analysis for your monitoring.	Where required and available, UKAS accredited labs will be used for analysis.

11. Unplanned Emissions to the Environment

11.1	<p>You should propose a leak detection and repair programme that is appropriate to the solvent composition. This should use industry best practice to manage releases, including from joints, flanges, seals and glands.</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>The PCC plant will be part of the Installation's maintenance programme and will include instrumentation to detect and monitor any leaks. Any leaks identified will be repaired by licenced contractors.</p> <p>A LDAR system will be put in place for the PCC plants.</p> <p>The CO₂ Compression Systems are provided with a single 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.</p> <p>The plant will be equipped with gas detection devices which will be linked to the site fire and gas system</p>
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12. Capture Level, Including During Flexible Operation

12.1	<p>Capturing at least 95% of the CO₂ in the flue gas is considered BAT. You can base this on average performance over an extended period (for example, a year). To achieve this, you should make sure the design capture level for flue gas passing through the absorber equates to at least 95% of the CO₂ in the total flue gas from the power plant. If you process less than the full flue gas flow, your capture rate will have to be correspondingly higher. Over the averaging period, your capture level may vary up or down. As the fraction of intermittent renewable generation in the UK rises, CCS power plants will need to start and stop more often, and possibly also operate at variable loads. It is therefore important that CO₂ can also be captured at high levels during these periods, including during start-up and shutdown, to maintain high average capture levels.</p> <p>A method to maintain capture at normal rates or higher at all times using solvent storage has been identified in the BAT Review. This, or alternatives that can achieve equivalent results, is considered BAT. If your PCC plant is not initially constructed with this capability, your permit application should show how you may retrofit it.</p>	<p>The expectation is that the PCC plants will demonstrate approximately 95% capture rates are achievable, under normal operation.</p> <p>The plant is a CHP, providing heat and power to the adjacent refineries and therefore required to be in continuous operation. Future operation will likely be flexible, i.e. ramping up and down instead of starting and stopping. Therefore, variable loads are less likely to impact capture rates. There will be minimal start-up and shutdowns.</p> <p>In addition, due to the availability of steam which can be easily used to start the capture plant and make it ready to accept flue gas, no special design measures are required to speed up start-up rate.</p>
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13. Compression

13.1	You should select CO ₂ compressors based on the expected duty. You should consider how any waste heat arising may be used.	The PCC plants will comprise geared compressors to carry out both the low and high pressure compression of the CO ₂ . The compressor selection has been undertaken based on the anticipated load(s).
13.2	For base load operation, you should use integrally geared units because they give the:	Integrally geared units are proposed, as the Installation is a baseloading plant.

Ref.	BAT Requirement	Response
	<ul style="list-style-type: none"> • Maximum full-load efficiency • Minimum number of compression trains 	
13.3	<p>For flexible and part-load operation, smaller compression trains (for example 2 at 50% compared to 1 at 100%) may be preferable. The use of different types of compressor or pump in series may also be preferable, to give greater flexibility at the expense of slightly lower full-load efficiencies.</p>	Not applicable.
14. Noise and Odour		
14.1	<p>The LCP BRef covers the noise impacts for the main power plant.</p> <p>Consider additional process steps in PCC technology that have high potential for noise and 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:</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 • Change of the frequency of the sound 	<p>A noise assessment has been undertaken in support of the Planning application made for the PCC plant, and includes an assessment of all potential sources of noise from the PCC plant, including but not limited to the compressors.</p> <p>Specific noise attenuation measures are yet to be confirmed for the project, however these will be confirmed with the EA in the detailed design phase.</p>
14.2	<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>Solvent will be stored appropriately to ensure minimal odour emissions. The Cansolv DC-103 solvent has very low volatility and therefore is not considered to represent a particular odour risk.</p>
15. Cooling		
15.1	<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 • dry cooling – direct air-cooled condensers and dry cooling towers 	<p>An assessment of potential cooling options for the PCC plants, comprising air cooled, water cooled and hybrid cooling systems has been undertaken to determine which represents BAT for the PCC plants. The assessment concludes that air cooled systems represent BAT for the PCC plants (see Appendix E).</p>
15.2	<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 aircooled condensers.</p> <p>It may also be possible to reuse cooling water after the main condensers for higher-temperature</p>	<p>The option to share water with the VPI CHP Power Plant cooling system was investigated but discounted. The CHP power output is constrained by insufficient cooling when the CHP is required to operate in unabated mode whilst the PCC plant is in standby/ short duration outage. In this scenario, the cooling water circulation for the PCC plants will be kept online.</p>

Ref.	BAT Requirement	Response
	cooling applications in the PCC plant. However, site specific water discharge temperature limits may be an issue for direct cooling.	
15.3	<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 	<p>Dispersion modelling has demonstrated that flue gas reheat is not required to aid dispersion of the emissions from the absorbers.</p> <p>Heat from the flue gas stream is low grade, and there are no opportunities to reuse this heat elsewhere.</p>
15.4	Lean and rich solvent storage may also help you achieve satisfactory PCC performance during periods of high cooling demand.	The VPI CHP Power Plant maintains a baseload production of steam which is available for start-up. Amine storage is therefore not required to improve start-up time.
15.5	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.	This guidance was used in the preparation of the Cooling BAT assessment (see Appendix E).
16. Discharge to Water		
16.1	<p>For discharges to water, you should refer to the guidance on surface water pollution risk assessment for your environmental permit.</p> <p>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'.</p>	Only waters that are uncontaminated will be discharged to water from the PCC plant area.
17. Climate Change Adaptation		
17.1	You need to integrate climate change adaptation into your management system.	The EA's Adapting to climate change: Combustion power guidance has been consulted ¹⁰ and a Risk Assessment has been completed and is provided in Appendix L.

¹⁰ [Combustion power: examples for your adapting to climate change risk assessment - GOV.UK \(www.gov.uk\)](https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/612222/Combustion_power_examples_for_your_adapting_to_climate_change_risk_assessment.pdf)

Appendix E – Cooling BAT Assessment

See separate .pdf report

Appendix F – Air Quality Assessment

See separate electronic folder with modelling files and supporting information.

Appendix G - CO₂ Venting Study

See separate .pdf report.

Appendix H – Noise Impact Assessment

See separate electronic folder with modelling files and supporting information.

Appendix I – Noise Management Plan

See separate .pdf report.

Appendix J - Qualitative Risk Assessment

Assessment of Fugitive Emission Risks

Hazard	Receptor	Pathway	Risk Management	Probability of Exposure	Consequence	Overall Risk
Escape of odour from stored chemicals	Local residents/ businesses beyond the Installation Boundary	Vapours/ odour carried on wind	<p>The PCC plants will use and store chemicals, which will be managed in accordance with appropriate management procedures.</p> <p>All raw materials will be stored in suitable sized above ground tanks and containers, provided with sufficient spillage containment, in accordance with the relevant material specifications.</p> <p>The Cansolv solvent has a low volatility and therefore is not considered to constitute an odour risk.</p>	Probability of exposure is considered to be very low due to management procedures and low volatility of the stored materials.	Complaints of odours/ smells in vicinity of local receptors	Very low
Escape of odour during operation	Local residents/ businesses beyond the Installation Boundary	Vapours/ odour carried on wind	<p>The PCC plant will be designed to ensure fugitive emissions will be minimised as far as possible through detailed design.</p> <p>As above re. Canosolv volatility.</p>	Probability of exposure is considered to be very low due to plant design and management procedures.	Complaints of odours/ smells in vicinity of local receptors	Very low
Escape of raw materials including hazardous chemicals	Local surface water and/ or groundwater	Flow by gravity/ drainage systems/ unsurfaced areas	<p>Storage arrangements appropriate to materials being stored; impermeable surfacing across the PCC plants; bunded storage facilities; limited external storage facilities; high and low level tank alarm systems; segregated drainage systems for offloading areas with interceptors and isolation points; and inspection and maintenance at regular intervals.</p> <p>All raw materials stored will be stored in appropriate containers, provided with sufficient spillage</p>	<p>Fugitive releases could reach surface water and/ or groundwater but appropriate design and management actions should prevent this from happening.</p> <p>All chemical storage tanks will be bunded to provide sufficient containment in the event of a tank/ containment failure.</p> <p>Probability is therefore low.</p>	Localised pollution of surface water and groundwater.	Low

Hazard	Receptor	Pathway	Risk Management	Probability of Exposure	Consequence	Overall Risk
			containment, in accordance with the relevant material specifications.			
Escape of wastes from PCC plants, including hazardous chemicals	Local surface water and/ or groundwater	Flow by gravity/ drainage systems/ unsurfaced areas	Storage arrangements appropriate to materials being stored; impermeable surfacing across the PCC plants; bunded storage containers with closed drainage systems; and inspection and maintenance at regular intervals. All materials stored will be stored in appropriate containers, provided with sufficient spillage containment, in accordance with the relevant material specifications.	Fugitive releases could reach surface water and/ or groundwater but appropriate design and management actions should prevent this from happening. All chemical storage tanks will be bunded to provide sufficient containment in the event of a tank/ containment failure. Probability is therefore low.	Localised pollution of surface water and groundwater.	Low

Assessment of Visible Plume Risks

Hazard	Receptor	Pathway	Risk Management	Probability of Exposure	Consequence	Overall Risk
Operation of PCC plants' emission stacks	Local residents/businesses beyond the Installation boundary	Dispersion by wind	<p>Visible plumes could potentially occur from the PCC plants' absorber stacks due to the lower temperature of release and the water content of the flue gas.</p> <p>An assessment has been undertaken using ADMS modelling to predict visibility of plumes from the absorber stack. The results show that the plumes are predicted to be visible for up to 85% of the time, with average plumes being <123m).</p>	Medium given location of the Installation, and applied management procedures.	Nuisance – visible plume	Low

Assessment of Accident Risks

Hazard	Receptor	Pathway	Risk Management	Probability of Exposure	Consequence	Overall Risk	
Fire	Local residents/ businesses beyond the Installation boundary. Site staff and infrastructure.	Emissions of smoke to the air and potentially firewater, foam, etc. to site drainage and soil/ groundwater and controlled waters	<p>Fire detection across all plant areas.</p> <p>Provision of a firefighting water supply with adequate flow and pressure to feed fire suppression systems.</p> <p>Use of sprinklers and/ or foam systems to protect: all raw materials and plant areas; fuel oil/ fuel gas burners; diesel and chemical tanks and bund areas; and accommodation areas.</p> <p>Use of portable extinguishers plant wide and smoke vents in designated areas.</p> <p>Installation designed to contain contaminated firewater and spillages within the Installation boundary and site drainage system, with dedicated firewater storage tanks and drainage diversion and containment systems.</p>	Appropriate design and management actions should allow the early detection of/ minimisation of the risk of fire spreading. Containment infrastructure is in place for firewater management.	Complaints of smoke/ smells in vicinity from local residential receptors. Localised pollution of surface water and soil/ groundwater.	Low	
Flooding of the Installation and associated contamination of flood waters with chemicals/ fuel stored on site	Local surface water and/ or groundwater	Flow by gravity/ drainage systems/ unsurfaced areas	<p>The flood defences in proximity to the Installation are considered to be in fair condition.</p> <p>Based on the information provided by the EA, it has been determined that the Installation is at a 'low' risk of flooding from tidal and fluvial sources risk of flooding (at the defence) up to the 0.5% AEP (1 in 200-year return period) flood event. The Environment Agency inspects these defences routinely to ensure potential defects are identified.</p> <p>Flood mitigation measures will be implemented on the PCC plants, a system would be put in place to safeguard the site occupants. Measures will include, but not be limited to, implementation of a Flood Response Plan.</p>	Low	The EA Flood Maps illustrate that the Installation (including the PCC plant area) is mainly located within Flood Zone 1 (i.e. a Low risk of flooding from tidal and fluvial sources). In addition, defences are in place and additional mitigation measures will be implemented.	Localised flooding of the PCC plants and neighbours. Potential pollution of surface water and groundwater from escape of chemicals.	Low
Vandalism to plant, equipment and infrastructure	Local residents/ businesses beyond the	Emissions resulting from failure/ reduced	Security fence, appropriate intruder alarms and CCTV cameras to be located at numerous locations on Site, with restricted entry; relevant	Negligible. Appropriate design and management	Complaints of odours in the vicinity of local receptors.	Low	

Hazard	Receptor	Pathway	Risk Management	Probability of Exposure	Consequence	Overall Risk
and associated loss of fuel/chemicals from site	Installation boundary, air, land and water. Site staff and Infrastructure.	performance of vandalised plant, equipment and infrastructure	signage; building envelope around a significant proportion of the operation/ process.	actions should prevent vandalism happening.	Localised pollution of surface water and groundwater. Potential for injury, damage to plant/ equipment.	

Appendix K – Climate Change Risk Assessment

Ref.	Requirements	Response
Summer daily maximum temperature		
This may be around 7°C higher compared to average summer temperatures now, with the potential to reach extreme temperatures as high as over 40°C with increasing frequency based on today's values.		
Impact 1	An increase in cooling water temperature may cause a drop in efficiency, higher temperature discharges or decrease in operation.	<p>Air coolers are to be employed for the PCC plants. The PCC plant will be designed to operate over a large range of ambient conditions. For example, the air-cooled exchangers would not be adversely affected by increased average air temperature.</p> <p>Extreme temperature events may lead to reduced efficiency of the PCC plant resulting in lower rates of carbon capture and there are no embedded planned controls for extreme temperatures (e.g., 40+ degrees). Extreme temperature events cause overheating of equipment causing damage to infrastructure components.</p> <p>Mitigation for this includes:</p> <ul style="list-style-type: none"> - Limiting operations during high temperatures - Some cabling will be buried underground, insulating against overheating in times of heatwaves. - All buildings will be designed to UK standards and specifications. - Maintenance inspections planned for operation.
Impact 2	The higher temperatures could lead to increased resistance of wiring circuits and in generators, with an increased risk of fire.	<ul style="list-style-type: none"> - Electrical equipment designed to operate in temperatures of up to 40° C.
Winter daily maximum temperature		
This could be up to 4°C more than the current average with the potential for more extreme temperatures, both warmer and colder than present.		
Impact 1	Increases in temperature may cause a drop in efficiency, but a lower risk than in summer.	<p>Extreme cold temperatures result in freezing of instrumentation and lines.</p> <p>Mitigation for this includes:</p> <ul style="list-style-type: none"> - Good plant design, heat tracing of any lines susceptible to freezing. - Winterisation of plant instruments (good instrument design).
Daily extreme rainfall		
Daily rainfall intensity could increase by up to 20% on today's values.		
Impact 1	Critical areas of the site could see flash flooding.	<p>Extreme rainfall events lead to surface water flooding and can cause damage to infrastructure, building surfaces and exposed utilities.</p> <p>Mitigation for this includes:</p> <ul style="list-style-type: none"> - Protection and raising of critical equipment. - Suitable storage and bunding of pollutants to protect from high rainfall events. Supported by a Site Emergency Response Plans.

- Installation of a suitable sustainable surface water drainage network and management system (SuDS) to protect from high rainfall events.
- Flood Resistance and Resilience Measures will be implemented as required, including:
 - i. pipelines and storage tanks designed to withstand the water pressures associated with high return period event flooding;
 - ii. tanks securely tethered in such a way to ensure the infrastructure remains secure should flooding occur;
 - iii. electrical supply entering the PCC plant from height and down to required connections;
 - iv. flood proofing including the use of water resistant coatings, use of galvanised and stainless steel fixings and raising electrical sockets and switches;
 - v. suitable waterproofing measures to development located below ground i.e. tanking below ground storage areas etc.
 - vi. make use of EA flood warnings and alerts; and
 - vii. define emergency access and egress route.
- The Flood Risk Assessment (FRA) carried out for the TCPA application has considered climate change within its assessment. It has assessed the PCC plant based on a 'high emissions' future scenarios including increases in extreme rainfall, flood flow and flash flood times.
- All buildings will be designed to UK standards and specifications.
- Maintenance inspections planned for operation.

Impact 2	Bunded areas could get flooded, reducing their capacity.	Bunds will be suitably designed, taking into account potential rainfall scenarios at detailed design stage. Consideration to bund level detection systems will also be given at detailed design. Bunds will be subject to frequent inspections, and in the event of extreme rainfall, the frequency of inspections will be increased.
Impact 3	Surface water run-off systems need to be clear and account for increased flows to prevent them being overwhelmed.	New, separate foul and surface water drainage system will be constructed for the PCC plant area. Further details on the design of the drainage system, including attenuation, restricted discharge to South Killingholme Drain and accounting for climate change (factor of 25%) is provided in the Drainage Strategy presented as Annex C in the FRA within Appendix 9A in ES Volume II (Appendix B).
Impact 4	Potential for increased site surface water and flooding.	As response for Impact 2 above.

Average winter rainfall

Average winter rainfall may increase by over 40% on today's averages.

Impact 1	Potential for increased site surface water and flooding.	
Impact 2	Bunded areas could get flooded, reducing their capacity.	As per responses provided for Daily extreme rainfall
Impact 3	Surface water run off systems need to be clear and account for increased flows to prevent them being overwhelmed.	

Sea level rise

Sea level rise which could be as much as 0.6m higher compared to today's level.

Impact 1	If a site is located near the coast there is potential increased risk of flooding.	<p>Sea level rise results in coastal flooding causing inundation of the PCC plant (or parts of the PCC plant) causing damage to infrastructure.</p> <p>Mitigation for this includes:</p> <ul style="list-style-type: none"> - Suitable storage and bunding of pollutants to protect from high rainfall events. Supported by a Site Emergency Response Plans. - Installation of a suitable sustainable surface water drainage network and management system (SuDS) to protect the PCC plant area from high rainfall events. - Flood Resistance and Resilience Measures will be implemented as required for the PCC plant area, including: <ol style="list-style-type: none"> i. pipelines and storage tanks designed to withstand the water pressures associated with high return period event flooding; ii. tanks securely tethered in such a way to ensure the infrastructure remains secure should flooding occur; iii. electrical supply entering the PCC plant from height and down to required connections; iv. flood proofing including the use of water resistant coatings, use of galvanised and stainless steel fixings and raising electrical sockets and switches; v. suitable waterproofing measures to development located below ground i.e. tanking below ground storage areas etc. vi. make use of Environment Agency flood warnings and alerts; and vii. define emergency access and egress route. - The Flood Risk Assessment (FRA) has considered climate change within its assessment. It has assessed the PCC plant based on a 'high emissions' future scenarios including increases in extreme rainfall, flood flow and flash flood times. - All buildings will be designed to UK standards and specifications.
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		- Maintenance inspections planned for operation.
Impact 2	Site surface water systems and effluent treatment plant may become overwhelmed and unable to discharge for prolonged periods due to backing up.	A new, separate foul and surface water drainage system will be constructed for the PCC plant area. Further details on the design of the drainage system, including attenuation, restricted discharge to South Killingholme Drain and accounting for climate change (factor of 25%) is provided in the Drainage Strategy presented as Annex C in the FRA within Appendix 9A in ES Volume II (Appendix B).
Drier summers		
Summers could see potentially up to 40% less rain than now.		
Impact 1	The site may be subject to cooling water restrictions of temperature and volume.	The PCC plant area has been designed to use air cooling, to minimise additional water use. The PCC plants have also been designed to maximum water reuse within the process where appropriate.
Impact 2	Potential risks of fire in biomass fuel and waste storage facilities as the ambient moisture levels would be lower.	<p>Prolonged periods of extreme heat and dry conditions could increase the risk of fires on site which can cause damage to infrastructure assets and become a potential safety hazard.</p> <p>Mitigation for this includes:</p> <ul style="list-style-type: none"> - Vegetation cleared around the Site. - Fire detection and protection built into the design of the PCC plant area e.g. fire hydrants, ring main of water. - Site Emergency Response Plans & team to manage and control fire risk.
River flow		
The flow in the watercourses could be 50% more than now at its peak, and 80% less than now at its lowest.		
Impact 1	The site may be subject to cooling water restrictions of temperature and volume.	The PCC plant area has been designed to use air cooling, to minimise additional water use.
Impact 2	There is likely to be an increased impact on the river due to an increased temperature and the impact of the emission on lower flows.	Not applicable.
Storms		
Impact 1	Storms could see a change in frequency and intensity. The unique combination of increased wind speeds, increased rainfall, and lightning during these events provides the potential for more extreme storm impacts. Storms and high winds could damage building structures with increased potential for fugitive emissions.	<p>Storm results in damage to structures/ equipment and resulting in repairs costs or reduced functionality, and/or unacceptable safety risks.</p> <p>Mitigation for this includes:</p> <ul style="list-style-type: none"> - Wind loadings will be considered within the detailed design of plant. - Quality control during construction and maintenance to secure at risk lagging. - The Flood Risk Assessment (FRA) considers climate change considerations of the 'high end' future scenarios including increases in extreme rainfall, flood flow and flash flood times. - Maintenance inspections planned for operation.

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- Procedures in place for extreme weather events (including wind) e.g. minimise maintenance during high wind events.
 - Lightning protections (rods) built into structures. Structures are also earthed.
 - In built protection measures to allow for safe shut-downs (fail-safe).
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Appendix L - Directors

Company name – VPI Immingham LLP

Registered office address – 4th Floor, Nova South, 160 Victoria Street, London, England, SW1E 5LB

Company number – OC300980

Details of LLP Designated Members

Name	Appointed on
IMMINGHAM ENERGY LIMITED	15 November 2001
VPI ICHP LIMITED	15 November 2001

Details of Secretaries

Secretary Name (Last name, First name)	Appointed on
ESSEX, Elizabeth	██████████

Details of Directors (Active only)

Director Name (Last name, First name)	Date of Birth	Appointed on
PIKUNIC, Jorge Pablo	██████████	16 December 2022
WHITE, Adam	██████████	16 December 2022
BRIGGS, Jonathan	██████████	20 June 2023
WARREN, Lee Stuart	██████████	20 June 2023

