Table of Contents

Contents

Tables

3. Proposed Developments Description, Need and Alternatives

3.1 Introduction

3.1.1 This Chapter of the Environmental Statement (ES) sets out the need for the Proposed Developments, a description of the Proposed Developments, and the alternatives that have been considered during the evolution of the Proposed Developments' design processes.

3.2 The Need for the Proposed Developments

3.2.1 The need for the Proposed Developments is defined by the UK Government's legally binding target to reach net zero by 2050. The Energy White Paper: Powering our Net Zero Future (HM Government, 2020) confirms the Government's support for Carbon Capture Usage and Storage ('CCUS') drawing upon the resource provided by the North Sea and new hydrogen technologies. The Government estimates (Introduction, page 15) that the measures in the Energy White Paper could reduce emissions across power, industry and buildings by up to 230 million tonnes of carbon dioxide (Mt CO_2e) in the period to 2032 and enable further savings in other sectors such as transport. In doing so, these measures could support up to 220,000 jobs per year by 2030. This is set out in Chapter 5: Policy Context and the Planning Statements that accompany the planning applications.

3.2.2 The Humber is the largest industrial cluster in the UK in terms of existing carbon dioxide (CO_2) emissions, emitting approximately 20 million tonnes of CO_2 per year. The Humber region produces construction materials, chemicals, food and fuel, generates 20% of the UK's electricity and produces a third of the UK's fuel. The Humber industrial cluster is also a major source of employment for the region and 20% of the regional economy derives from energy intensive industry.

3.2.3 The Proposed Developments aim to remove 95% of CO_2 emissions (3.8 million tonnes of CO_2 per year) from two of the large industrial processes in the Humber cluster – the Humber Refinery's Fluid Catalytic Cracker (FCC) and the VPI Immingham Combined Heat and Power (CHP) Plant gas turbines 1 and 2 (GT1 and GT2). This represents a 19% reduction in the overall emissions from the Humber industrial cluster. Progress of the Proposed Developments is subject to the necessary consents being granted and government policy/ funding support being in place to enable final investment decisions to be made.

3.2.4 The Proposed Developments will also create employment during construction and safeguard around 20,000 direct and indirect jobs in the Humber region.

3.2.5 The alternative 'do-nothing' scenario is described in Section 3.9 of this Chapter including the reasons for the Applicants to proceed with the Proposed Developments.

3.3 Description of the Proposed Developments

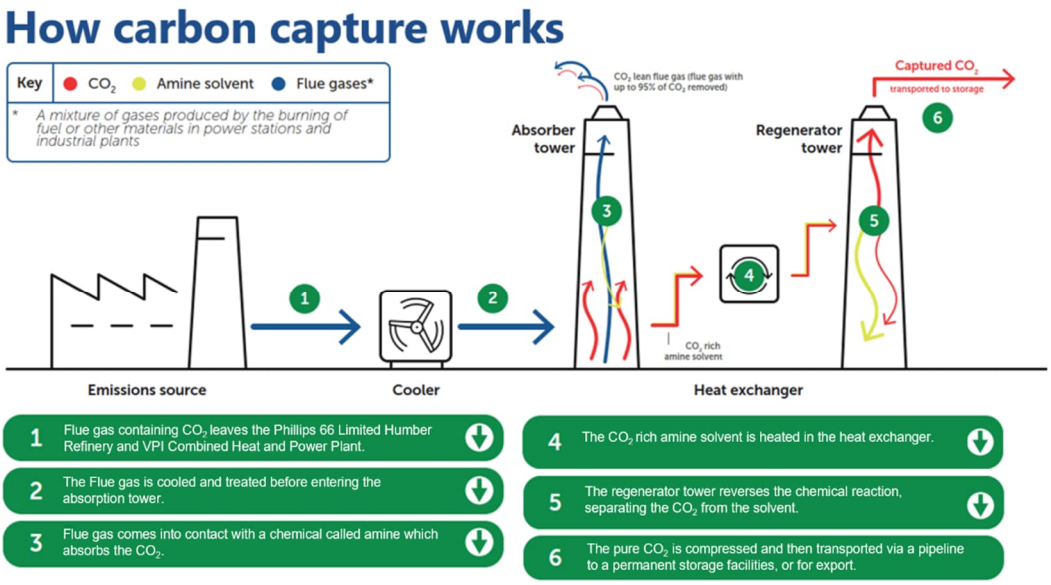
3.3.1 As described in Chapter 1: Introduction and EIA Methodology, this ES relates to two Proposed Developments – the Proposed VPI Development and the Proposed Phillips 66 Development – which together comprise the first phase of the Humber Zero project.

3.3.2 The Proposed Developments are necessarily located adjacent to the existing activities that are to be decarbonised (namely the Humber Refinery FCC and the VPI Immingham CHP Plant), but they are also well situated to connect into either the Viking CCS CO_2 gathering network and/or the Humber Low Carbon Pipelines CO_2 gathering network for transport to storage sites under the North Sea. Development Consent Order applications for both of these

CO_2 gathering networks are being progressed by Harbour Energy and National Grid respectively, and are due to be submitted in mid 2023.

3.3.3 Plate 3.1 below provides a high-level overview of the post-combustion carbon capture (PCC) process.

Plate 3.1: Summary of the post-combustion carbon capture (PCC) process



3.3.4 The Proposed VPI Development will comprise a PCC plant and associated facilities for capturing CO_2 from two of the gas turbines (GT1 and GT2)[1] and two auxiliary boilers at the VPI Immingham CHP Plant.

3.3.5 The Proposed Phillips 66 Development will comprise a PCC plant and associated facilities for the FCC at the Humber Refinery.

3.3.6 The water, steam and power required for the Proposed Developments will be supplied from existing Humber Refinery systems and the VPI Immingham CHP Plant.

3.3.7 The PCC facilities will be designed for 95% CO_2 capture during steady state operation. It is intended that CO_2 will be exported at high pressure (dense phase) via an interface to a CO_2 gathering network adjacent to the Sites.

3.3.8 The indicative layouts for each of the Proposed Developments are shown on Figures 3.1 and 3.2.

3.3.9 The Proposed Phillips 66 Development will include the following components:

- FCC flue gas waste heat exchanger for energy recovery;
- ducting (including ducting over an existing internal access road) to connect the FCC unit to the Phillips 66 PCC plant;
- flue gas pre-treatment using Selective Catalytic Reduction (SCR), a wet gas scrubber and wet electrostatic precipitator with associated air-cooled heat exchangers;
- one PCC unit with associated absorber, stack, stripper/ regenerator, thermal reclaimer unit and air-cooled heat exchangers/ fin fans;
- low pressure and high pressure CO_2 vent stacks for use during start up, shut down and emergencies only;

[1] The third gas turbine is proposed to be converted to hydrogen firing in future as part of the wider Humber Zero project.

- CO_2 compression facility with associated air-cooled heat exchangers/ fin fans;
- oxygen removal and dehydration facilities;
- CO_2 metering and a pipeline connecting the PCC plant and compression facilities to the CO_2 gathering network interface, including a pipeline crossing of the Phillips 66 railway sidings and Network Rail railway line;
- on-site electrical substation;
- caustic, solvent and other chemical offloading and storage facilities;
- utilities (including chillers, steam generator and air compressors)
- internal access roads;
- surface water and foul water drainage systems;
- construction and maintenance laydown areas; and
- a new site access from Eastfield Road.

3.3.10 The Proposed VPI Development will include the following components:

- ducting to connect GT1, GT2 and the auxiliary boilers to the VPI PCC plant;
- two PCC units (or 'trains'), each with associated blower, direct contact cooler, absorber, stack, stripper/ regenerator, thermal reclaimer unit and air-cooled heat exchangers;
- a CO_2 vent stack for use during start up, shut down and emergencies only;
- CO_2 compression facility with associated air-cooled heat exchangers;
- oxygen removal and dehydration facilities;
- CO_2 metering and a pipeline connecting the PCC plant and compression facilities to the CO_2 gathering network interface;
- on-site electrical substations;
- caustic, solvent and other chemical offloading and storage facilities;
- utilities (including chillers, steam generator, hydrogen package and air compressors);
- internal access roads;
- surface water drainage system
- realignment of the existing ditch (South Killingholme Drain) within the VPI Site;
- construction and maintenance laydown areas; and
- a new site access from Rosper Road.

3.3.11 Each of the key components is described in further detail below.

3.3.12 The maximum dimensions of the largest components are set out in Section 3.4 (Design Parameters). In order to ensure a robust assessment of the likely significance of the environmental effects of the Proposed Developments, the EIA has been undertaken adopting the principles of the 'Rochdale Envelope' approach where appropriate. This involved assessing the maximum (or where relevant minimum) parameters for the elements where flexibility needs to be retained. As such the ES presents a reasonable worst case assessment of the Proposed Developments.

3.4 Components of the Proposed Developments

3.4.1 This section provides further detail on the components of the Proposed Developments listed at paragraphs 3.3.9 and 3.3.10 above.

Phillips 66 Flue Gas Waste Heat Exchanger and Flue Gas Pre-Treatment

3.4.2 A waste heat exchanger will extract some of the heat from the FCC flue gas for energy recovery for the PCC plant.

3.4.3 Sulphur oxides (SO_x), nitrogen oxides (NO_x) and particulates levels in the FCC flue gas are regulated by the existing Environmental Permit, but levels will need to be further reduced before the flue gas enters the absorber to improve the effectiveness of the PCC process as part of the Proposed Phillips 66 Development. (This is not required for the Proposed VPI Development because levels of SO_x, NO_x and particulates are already lower in the CHP Plant flue gas.)

3.4.4 Ducting will be installed to divert the flue gas from the existing FCC stack to the flue gas pre-treatment facilities.

3.4.5 The Phillips 66 flue gas pre-treatment will comprise:

- SCR (to remove NO_x) using urea or aqueous ammonia to covert NO_x into nitrogen and water vapour;
- a wet gas scrubber using water sprays to quench the flue gas to reduce SO_x and particulates; and
- a wet electrostatic precipitator using electrostatic forces to reduce aerosols and fine particulates.

Phillips 66 and VPI Carbon Capture and Associated Stacks

3.4.6 Both the Phillips 66 and VPI Developments include the same processes for the removal of CO_2 from the existing flue gases. Both Applicants have independently selected the same technology provider (Shell) and the same amine solvent (known as CANSOLV DC-103).

3.4.7 In the Proposed Phillips 66 Development the flue gas will enter the PCC process from the pre-treatment process (which will have already cooled the flue gas to a suitable temperature for the PCC process to work most effectively).

3.4.8 In the Proposed VPI Development the flue gas will be diverted from the CHP Plant directly to one of two PCC trains located to the south of the CHP Plant, where the flue gas will first be cooled using a direct contact cooler to enable the PCC process to more effectively absorb CO_2.

3.4.9 The CO_2 'rich' flue gas will enter the CO_2 absorber tower where it will come into contact with the amine solvent, which will absorb 95% of the CO_2. The CO_2 lean flue gas (flue gas with 95% CO_2 removed) will be released from the absorber tower, and the CO_2 rich amine will be heated to separate the CO_2 from the amine in the regenerator towers (also known as CO_2 stripper towers). The Proposed Phillips 66 Development will have one absorber tower and one regenerator tower, and the Proposed VPI Development will have two of each (one of each for each PCC train).

3.4.10 The majority of the amine will be cooled using air cooled heat exchangers and treated for re-use in the PCC plants. A very small quantity of amine will be 'lost' from the process (released with the CO_2 lean flue gas from the absorber towers) and the amine will also degrade over time so 'fresh' amine will be required throughout the operation of the PCC plants. The thermal reclaiming units at the PCC plants will treat the amine to arrest amine degradation and limit emissions from the absorber towers.

Phillips 66 and VPI CO_2 Venting, Treatment and Compression

3.4.11 The gaseous CO_2 will be saturated with water and will contain traces of oxygen which will need to be removed to achieve the specification required by the CO_2 gathering network operators.

3.4.12 During start up and shut down of the PCC plants (for example before and after a maintenance outage) when the required CO_2 specification cannot be achieved, CO_2 may need to be safely vented to the atmosphere. CO_2 venting may also be required during emergency situations to ensure safe operation of the PCC plants. CO_2 vent stacks are therefore included as part of both the Proposed Developments, with the height of the emission point (approximately 40 m) designed to ensure safe dispersion of the CO_2.

3.4.13 The captured CO_2 will need to be compressed ready for injection into the CO_2 gathering network. Compression will be undertaken in two phases – first low pressure (LP) compression to approximately 30 to 40 barg, then high pressure (HP) compression to 135 barg (the pressure required for injection into the CO_2 gathering network).

Phillips 66 and VPI CO_2 Transport to CO_2 Gathering Network

3.4.14 The Proposed Developments will connect to the Viking CCS network and/ or Humber Low Carbon Pipelines to transport CO_2 to a storage site under the North Sea. As noted earlier, both of these CO_2 gathering networks are the subject of DCO applications due to be submitted in mid 2023 by Harbour Energy and National Grid respectively.

3.4.15 At this stage it is important for the Proposed Developments to retain flexibility regarding the final CO_2 gathering network, so the Proposed Development layouts allow for connection at a CO_2 gathering network tie-in compound in the available land to the south of the VPI PCC plant.

3.4.16 The Phillips 66 Development includes a CO_2 pipeline and associated control cables across the Network Rail railway line between the Humber Refinery and the land south of the VPI Immingham CHP Plant. The CO_2 pipeline and cables will be routed over the existing pipe bridge. The design of this crossing has been discussed with Network Rail.

3.4.17 Metering and analysing will also be provided to measure the quantity and quality of CO_2 leaving each of the Proposed Developments.

Other Components of the Proposed Phillips 66 Development

3.4.18 In addition to the main components described above (flue gas pre-treatment, CO_2 capture, compression and connection to the CO_2 gathering network), the Proposed Phillips 66 Development will also require:

- an electrical substation to supply the required electrical power to the PCC plant;
- chemical offloading storage and distribution facilities for caustic, solvent and other chemicals required for the PCC plant;
- solvent disposal and purge water disposal;
- utilities to supply the PCC plant with cooling, steam and compressed air requirements;
- internal access roads providing access around the Proposed Phillips 66 Development and connecting the Proposed Phillips 66 Development to existing roads in and around the Refinery;
- surface and foul water drainage systems, connecting to the existing waste water treatment plant at the Humber Refinery for treatment and discharge to South Killingholme Drain (see paragraphs 3.6.15 to 3.6.16 below and Appendix 9C Drainage Strategies);
- construction and maintenance laydown areas and welfare facilities, which are expected to be located on existing areas of hardstanding within the Phillips 66 Site; and
- a new site access from Eastfield Road, which together with an existing access from Eastfield Road in the north-west corner of the Refinery will allow one way entry and one way exit from the Phillips 66 Development.

Other Components of the Proposed VPI Development

3.4.19 In addition to the main components described above (CO_2 capture, compression and connection to the CO_2 gathering network), the Proposed VPI Development will also require:

- up to four electrical substations to supply the required electrical power to the PCC plant;
- chemical offloading storage and distribution facilities for caustic, solvent and other chemicals required for the PCC plant;
- internal access roads providing access around the Proposed VPI Development and connecting the Proposed VPI Development to existing roads in and around the CHP Plant;
- surface water drainage system with an attenuation lagoon to manage surface water runoff prior to discharge to South Killingholme Drain (see paragraphs 3.6.17 to 3.6.18 below and Appendix 9C Drainage Strategies);
- realignment of South Killingholme Drain through the VPI Site to facilitate the VPI Development, with the majority of the realigned drain remaining open (approximately 441 m) but with the westernmost section (approximately 136 m) being culverted to maintain an existing access route, and creation of up to four temporary crossings of the realigned Drain to be used during the Proposed VPI Development's construction and then removed prior to operation – this has been discussed with the North East Lindsey Internal Drainage Board (NEL IDB) who manage the Drain for local flood risk management;
- construction and maintenance laydown areas, which are expected to be located on existing hardstanding within the existing CHP Plant and in the southernmost part of the VPI Site; and
- a new site access from Rosper Road in the north-east corner of the PCC plant development area (near the junction with Marsh Lane) approximately 50 m to the north of the existing 'middle' access from Rosper Road into the VPI Site.

Access

3.4.20 The Proposed Developments will utilise the existing accesses to the VPI Site and to the Phillips 66 Site (see Figures 2.1) during both construction and operation.

3.4.21 A new access (also shown on Figure 2.1) is also proposed to be constructed from the public highway (Eastfield Road) into the north-west area of the Phillips 66 Site. This new access will be used as the main HGV and abnormal load access and egress during construction use. It is also proposed to provide egress for operational deliveries (which will access via the existing access road on Eastfield Road approximately 170 m to the north). Staff access during construction and operation will be via the existing access points into the Refinery and associated car parking areas.

3.4.22 A new access (also shown on Figure 2.1) is also proposed to be constructed from the public highway (Rosper Road) into the VPI Site. This new access will be used as the main HGV access and egress during construction and for maintenance and emergency use during operation. Staff access will be via the existing main entrance to the CHP Plant.

Landscaping and Biodiversity

3.4.23 Existing boundary vegetation will be retained (with the exception of approximately 17 m of hedgerow which will need to be removed at the location of the proposed new access to the Phillips 66 Site on Eastfield Road) and the trees either side of the Network Rail railway line will be retained and protected (with the exception of two small areas of low value trees (G9 and G13 in Appendix 2A) which encroach into the VPI construction laydown area and a small area of low value trees (G14) which encroach into the Phillips 66 development area and may therefore need to be removed). An arboricultural survey has been undertaken to identify the root protection areas (see Appendix 2A in ES Volume II).

3.4.24 Existing landscape planting is in place along Eastfield Road, providing a buffer between the Humber Refinery and Eastfield Road. There is limited space within both Sites for landscaping and biodiversity habitat creation but opportunities to provide landscape planting within the Sites will be considered at the detailed design stage.

3.4.25 A Biodiversity Net Gain assessment has been undertaken and a Biodiversity Net Gain Strategy accompanies each planning application. This identifies options for off-site biodiversity enhancements to achieve 10% Biodiversity Net Gain for each of the Proposed Developments, the details of which are proposed to be secured by planning conditions.

Security Fencing and CCTV

3.4.26 The Humber Refinery is already securely fenced with CCTV monitoring equipment so no additional security fencing or CCTV is proposed for the Proposed Phillips 66 Development.

3.4.27 Whilst the VPI Immingham CHP Plant also has existing security fencing and CCTV monitoring equipment, additional security measures are proposed for the proposed VPI PCC plant to the south of the existing CHP Plant in accordance with current industry best practice. This will comprise additional CCTV cameras and 2.4 m high perimeter fencing.

External Lighting

3.4.28 Lighting will be provided to achieve the level of illumination necessary for safe operation and maintenance of the Proposed Developments.

3.4.29 External lighting will be of LED type positioned to minimise light spill from the boundaries of the Sites. Where appropriate outdoor lighting will be switched on and off centrally by means of photocells or timers.

3.4.30 The lighting will be designed to reduce glare and sky glow and to minimise energy use and associated carbon emissions.

3.4.31 The Proposed VPI Development's absorber stacks will be fitted with aviation warning lighting as required by the Civil Aviation Authority. This is not expected to be required for the Proposed Phillips 66 Development's tallest structures because there are existing taller structures within the Refinery.

Design Parameters

3.4.32 The technical assessments presented in the ES are based on the indicative layouts presented in Figures 3.1 and 3.2, and the site layout parameters plans presented in Figures 3.3 and 3.4.

3.4.33 The exact positions of each component including the stacks cannot be fixed as the detailed design has not been completed. Each technical assessment presented in this ES has therefore adopted a relevant worst case using the parameters plans (Figures 3.3 and 3.4) to represent the worst case impact at receptors.

3.4.34 Tables 3.1 and 3.2 sets out the maximum dimensions of the largest components of the Proposed Developments which have been used as the basis for the various technical assessments presented in this ES to ensure a robust assessment based on reasonable and appropriate worst case assumptions. This approach is referred to as 'the Rochdale envelope' approach.

Table 3.1: Maximum design parameters for Proposed Phillips 66 Development

Development Component	Maximum Design Parameter
Absorber column and associated stack	Up to 70 m height above ground level (top of stack at 79.5 m AOD)
Wet gas scrubber stack	Up to 70 m above ground level (top of stack at 75.5 m AOD)
CO_2 regenerator/ stripper column	Up to 65 m height above ground level (top of column at 74.5 m AOD)

Table 3.2: Maximum design parameters for Proposed VPI Development

Development Component	Maximum Design Parameter
Absorber column and associated stack	Up to 110 m height above ground level (114.9 m AOD)
CO_2 regenerator/ stripper column	Up to 60 m height above ground level (64.9 m AOD)

3.5 Construction

3.5.1 The construction process for the Proposed Developments is set out Chapter 4: Construction Programme and Management. This provides information on construction timing, approach and methods for both the Proposed Phillips 66 Development and the Proposed VPI Development.

3.6 Operation

Hours of Operation

3.6.1 The Proposed Developments will be designed to operate 24 hours a day, 7 days a week as per the existing Humber Refinery FCC and VPI Immingham CHP Plant.

Staff

3.6.2 The Proposed Developments will be operated as part of the wider Refinery and CHP Plant operations. The Proposed Phillips 66 Development will create approximately 15 new full time equivalent (FTE) jobs and the Proposed VPI Development will create approximately 50 new FTE roles.

Process Inputs Including Chemicals, Electricity, Water and Steam

3.6.3 The Proposed Developments will use various raw materials during operation, which will be delivered by road.

3.6.4 Materials including chemicals to be stored and used within the Proposed Developments will be subject to control via the Environmental Permits, Hazardous Substances Consents (where applicable), Control of Major Accident Hazards (COMAH) licences (where applicable) and other necessary consents required, and are anticipated to include the following:

- caustic;

- activated carbon;
- antifoam agent;
- amine (Shell CANSOLV solvent DC-103);
- sodium carbonate;
- hydrogen;
- silica gel;
- ammonia (for Phillips 66 only); and
- coagulant and flocculant.

3.6.5 All liquid chemicals stored on site will be kept in bunded controlled areas within a volume of 110% of storage capacity and be appropriately segregated, in order to reduce the risk of contamination.

3.6.6 Odour will be controlled where relevant by appropriate storage, for example ammonia will be delivered to site and stored in sealed tanks to avoid any nuisance odours.

3.6.7 The potential for odour to occur from the amine solvent use and storage will be dependent on the volatility of the CANSOLV DC-103 solvent. The solvent has a low volatility, a boiling point of 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.

3.6.8 The PCC processes will also have electricity, water and steam demands. Electricity and steam will be supplied from the CHP Plant (which already supplies these utilities to the Refinery) and water will be supplied from Anglian Water via the existing Refinery and CHP Plant water supply network. The water demand for the PCC processes will result in approximately 10% increase in water demand (to be sourced from Anglian Water) for the Phillips 66 Humber Refinery and the VPI Immingham CHP Plant. Water used in the PCC processes will require treatment to generate demineralised water; other water demands include firewater.

Process Outputs Including Emissions to Air and Waste Management

3.6.9 The Proposed Phillips 66 Development will introduce three new emission sources to the air:

- the wet gas scrubber, which will emit treated flue gas (diverted from the existing FCC stack) during times when the PCC plant is not operational, e.g. maintenance outages;
- the absorber, which will emit the pre-treated, CO_2 lean FCC flue gas; and
- a CO_2 vent stack for use during start up, shut down, and emergencies only.

3.6.10 The Proposed VPI Development will introduce three new emission sources to the air:

- two absorbers, which will emit the CO_2 lean CHP Plant flue gas; and
- a CO_2 vent stack for use during start up, shut down, and emergencies only.

3.6.11 The PCC processes will generate waste materials which will be collected, stored and managed in accordance with best practice and current site waste management policies. Waste materials will include:

- waste from site offices; and
- waste from the PCC plant.

3.6.12 Chapter 16: Materials and Waste provides the findings of an assessment of the likely significant effects on materials and waste as a result of the Proposed Developments.

Process Cooling

3.6.13 Following a Best Available Technique (BAT) assessment of cooling options, both the Proposed Developments have been designed to use predominantly air cooling, with the use of evaporative water cooling during high ambient temperatures and for the chilling of CO_2 before export to the transport and storage network. This is largely due to the limited water resources available in the area, and limited impact on the PCC plants' efficiency.

Site Drainage and Wastewater Treatment

3.6.14 The drainage strategies for the Proposed Developments are set out in Appendix 9C.

3.6.15 The Phillips 66 Site areas within the existing Humber Refinery will be drained as at present with all process and non-process drainage collected and treated at the Refinery's waste water treatment plant before being discharged into South Killingholme Drain to the east of the Refinery in accordance with the existing discharge permit (no changes are expected to be required), and foul wastewater discharged to Anglian Water sewer. Some liquid effluents (e.g. from the new solvent (amine) drain system for the PCC plant) will be collected and tankered off site for disposal.

3.6.16 The Proposed Phillips 66 Development in areas outside the Refinery will not generate any foul drainage or create new areas of hardstanding that require surface water drainage.

3.6.17 The VPI Site areas within the existing CHP Plant will be drained as at present with all uncontaminated surface water being collected, attenuated and discharged to South Killingholme Drain via a separation pond, and all foul drainage being collected and treated at the CHP Plant wastewater treatment plant before being discharged to the off-site ditch via a separation pond.

3.6.18 A new drainage system will be installed as part of the Proposed VPI Development to the south of the CHP Plant. Some liquid effluents (e.g. degraded solvent waste) will be collected and tankered off site for disposal. Uncontaminated surface water will be collected and attenuated on site before being discharged to South Killingholme Drain. Surface water from areas where there is potential for:

- hydrocarbon contamination (e.g. from pumps and compressors) will pass through an oil interceptor before entering the attenuation pond;
- amine contamination will be collected and tested before discharge to the attenuation pond or tankered off site; and
- contamination from spillages during loading and unloading operations will be directed to a holding tank and tankered off site.

Maintenance

3.6.19 The objective of plant maintenance is to ensure the Proposed Developments operate safely and reliably, and inspection and maintenance activities have informed the Proposed Developments' layouts.

3.6.20 Routine maintenance will be planned and scheduled as for the existing Humber Refinery and VPI Immingham CHP Plant, with major maintenance outages/ turnarounds (which require temporary shut down) taking place approximately every three to six years. Maintenance activities require additional contractors to work on site.

3.6.21 The Proposed Developments will each have an initial design life of 25 years, although the operational life could potentially be extended subject to market conditions.

Hazard Prevention and Emergency Planning

3.6.22 The Applicants' aim is to protect human health by safely and responsibly managing activities on site. A Health and Safety Plan covering the works, commissioning and operation of the Proposed Developments will be prepared by each Applicant. For design and construction, a

competent and adequately resourced Principal Contractor will be appointed. The Applicants will ensure that its own staff, its designers and contractors follow the Approved Code of Practice (ACoP) laid down by the Construction (Design and Management) (CDM) Regulations 2015.

3.6.23 Written procedures clearly describing responsibilities, actions and communication channels will be available for operational personnel dealing with emergencies. Procedures will be externally audited, and contingency plans written in preparation for any unexpected complications.

3.6.24 The inventory of materials to be stored on the Sites will be finalised through the respective detailed designs. However, where storage of hazardous materials, individually or in-combination exceeds the relevant thresholds, separate permissions will be sought from the HSE and local planning authority for their storage, under the COMAH and Hazardous Substance Consent regimes respectively. All chemical storage will also be regulated by the Environment Agency through the environmental permits that will be required for the operation of the Proposed Developments.

3.6.25 As set out in Chapter 18: Major Accidents and Disasters, carbon dioxide is not harmful to human health at low concentrations, it is not flammable, and it will not support combustion. As the concentration of carbon dioxide in air rises, the hazardous effects on people and the environment increase. However, compared with other materials, such as natural gas and ethylene, the risks of harm (e.g. of asphyxiation or freeze burns) is relatively low. The key risk relates to its toxicity at elevated concentrations and potential to act as an asphyxiant gas in low lying locations or confined spaces should it displace air from these locations due to its density being higher than that of air.

3.6.26 Guidance and best practice information for carbon capture technology and transport via pipeline is available from the Health and Safety Executive (HSE). Carbon dioxide is not currently defined as a dangerous substance under the COMAH Regulations 2015 and the status of the Proposed Developments relating to the COMAH Regulations 2015 has not yet been confirmed. Guidance and best practice information for PCC is however, available from the HSE. The HSE does not currently provide Land Use Planning (LUP) advice for carbon dioxide capture, although for LUP purposes, HSE uses Dangerous Toxic Load (DTL) to describe a substance's airborne concentration and duration of exposure which would produce a particular level of toxicity in the general population. This advice has been considered in designing the Proposed Developments including safety distances from high pressure carbon dioxide equipment on the Sites.

Environmental Management

3.6.27 The Proposed Developments will operate under Environmental Permits from the Environment Agency (as variations to the existing Permits for the Humber Refinery and the VPI Immingham CHP Plant) which will stipulate the required environmental monitoring and controls to be employed, including emissions monitoring systems.

3.6.28 The Proposed Developments will be operated in line with existing environmental management systems (EMS) for the Refinery and CHP Plant, which are certified to International Standards Organisation (ISO) 14001. The EMS's will outline requirements and procedures required to ensure that each Proposed Development is operating to the appropriate standard, including procedures for:

- sampling and analysis of emissions using CEMS prior to discharge from the stacks in accordance with the Environmental Permits;
- storage of chemicals;
- waste management and disposal;
- surface and foul water drainage; and
- planned maintenance.

3.7 Decommissioning

3.7.1 At the end of the Proposed Developments' design lives, it is expected that the Proposed Developments will have some residual life remaining. A decision whether to continue to operate the PCCs would then be made based on the market conditions prevailing at that time.

3.7.2 At the end of their operating lives, the PCCs will be decommissioned in line with relevant standards and best practices and in accordance with permit conditions and any relevant legal requirements. This will include at minimum safe shutdown, purging and isolation of equipment along with removal of any hazardous chemicals and substances, up to full demolition and restoration of the Sites. It should be noted that the PCCs will form part of larger operational sites for which they are not the primary activity, and it is therefore conceivable that the operational sites could continue to operate with the PCCs decommissioned. Surrender of site permits will be undertaken in accordance with all regulatory obligations.

3.7.3 The bulk of the relevant plant and equipment will have some limited residual value as scrap or recyclable materials, and the demolition contractor will be encouraged to use materials that could be recycled.

3.7.4 Prohibited materials such as asbestos, polychlorinated biphenyls (PCB), ozone depleting substances and carcinogenic materials will not be allowed within the design of the Proposed Development. Other materials recognised to pose a risk to health, but which are not prohibited, will be subject to a detailed risk assessment.

3.7.5 Prevention of contamination is a specific requirement of the Environmental Permits for the operation of the Proposed Developments and therefore the Proposed Developments are being designed such that it will not create any new areas of ground contamination or pathways to receptors as a result of construction or operation. Once the relevant plant and equipment have been removed to ground level, it is expected that the hardstanding and sealed concrete areas will be left in place. Any areas of the Proposed Developments which are to be decommissioned that are below ground level will be backfilled to ground level to leave a levelled area.

3.7.6 Decommissioning Plans (including Decommissioning Environmental Management Plans (DEMPs)) would be produced at the time of decommissioning each Proposed Development and agreed with the Environment Agency as part of the Environmental Permitting and site surrender process. The DEMPs would consider in detail all potential environmental risks on the Sites and contain guidance on how risks can be removed or mitigated during the decommissioning and demolition.

3.7.7 The Decommissioning Plans will include outline programmes of works. It is anticipated that it would take up to a year to decommission each Proposed Development, with demolition following thereafter, i.e., taking approximately two years to complete.

3.7.8 During decommissioning and demolition there will be a requirement for the provision of office accommodation and welfare facilities.

3.7.9 Any demolition contractor would have a legal obligation to consider decommissioning and demolition under the CDM Regulations 2015, or the equivalent prevailing legislation at that time.

3.7.10 Decommissioning activities will be conducted in accordance with the appropriate guidance and legislation at the time of the Proposed Developments' closure. All decommissioning activities will be undertaken in accordance with the waste hierarchy. Materials and waste produced during decommissioning and demolition will be stored in segregated areas to maximise reuse and recycling. All materials that cannot be reused or recycled will be removed from the Sites and transferred to suitably permitted waste recovery/ disposal facilities. It is anticipated that a large proportion of the materials resulting from demolition will be recycled and a record will be kept in order to demonstrate that the maximum level of recycling and reuse has been achieved.

3.7.11 Upon completion of each Proposed Development's decommissioning programme, including any remediation works that might be required, the Environment Agency will be invited to witness a post-decommissioning inspection by site staff. All records from the decommissioning process will be made available for inspection by the Environment Agency and other relevant statutory bodies, in accordance with the Environmental Permit requirements.

3.7.12 In the light of the control measures set out above that would form part of the proposed DEMPs, decommissioning is not anticipated to present any significant environmental effects beyond those assessed for the construction phase of the Proposed Development.

3.8 Embedded Environmental Mitigation

3.8.1 The Proposed Developments are a form of environmental mitigation for the existing Humber Refinery FCC and VPI Immingham CHP Plant, given that the purpose of the Proposed Developments is to capture existing CO_2 emissions before they enter the atmosphere.

3.8.2 The design of the Proposed Developments will be required to meet relevant legislation, standards and guidance including:

- The Environmental Permitting Regulations 2016 (as amended);
- The Pollution Prevention and Control Act 1999;
- The Water Environment (Water Framework Directive) (England and Wales) Regulations 2017;
- The Environmental Noise (England) Regulations 2006;
- The Hazardous Waste (England and Wales) Regulations 2005;
- The Environmental Protection Act 1990;
- The Industrial Emissions Directive (Directive 2010/75/EU);
- The Environment Agency guidance 'Post-combustion carbon dioxide capture: best available techniques (BAT)';
- BAT reference documents (BREFs) for both Large Combustion Plants and Refining; and
- UK and EU ambient air quality standards.

3.8.3 Each technical chapter of this ES (Chapters 6-17) sets out the embedded mitigation (impact avoidance and mitigation measures) that are taken into account in the assessment.

3.9 Alternatives Considered

Requirement for Consideration of Alternatives

3.9.1 Schedule 4 of the Town and Country Planning (Environmental Impact Assessment) Regulations 2017 states that an ES must include "*A description of the reasonable alternatives (for example in terms of development design, technology, location, size and scale) studied by the developer, which are relevant to the proposed project and its specific characteristics, and an indication of the main reasons for selecting the chosen option, including a comparison of the environmental effects.*"

3.9.2 The consideration of alternatives and design evolution has been undertaken with the aim of developing PCC plants for the FCC and CHP Plant to meet the identified national need for industrial decarbonisation, while avoiding and/or reducing adverse environmental effects (following the mitigation hierarchy of avoid, reduce and, if possible, remedy), as well as maintaining operational efficiency and cost-effectiveness, and considering other relevant matters such as available land and planning policy.

3.9.3 The alternative of ceasing operation of the FCC and CHP Plant GT1/ GT2/ auxiliary boilers is not considered to be an option given the economic significance of the Humber Refinery and the VPI Immingham CHP Plant which supplies heat and power to the Humber Refinery and the adjacent Lindsey Oil Refinery and power to the national grid.

Alternative Sites

3.9.4 Alternative sites with the Applicants' control were considered, however the nature of the Proposed Developments involve retrofitting existing infrastructure with carbon capture technologies, and therefore proximity to the existing units is a key consideration.

3.9.5 The FCC stack is the largest CO_2 emitting unit (stack) at the Humber Refinery so has been selected for the first PCC project at the Humber Refinery, and the selected location for the Proposed Phillips 66 Development has been chosen for its availability and proximity to the FCC and its stack. Other emission points at the Refinery may be retrofitted with PCC in future (and the currently Proposed Phillips 66 Development may in fact enable other such developments by providing a CO_2 compression network within the Humber Refinery and establishing a tie-in to the CO_2 gathering network).

3.9.6 The location for the Proposed VPI Development was also selected for its availability and proximity to the CHP Plant. Land to the north of the CHP Plant is not available as it is already allocated to the potential development of an Open Cycle Gas Turbine (OCGT) Power Station for which a Development Consent Order was granted in 2020. Land to the west comprises the existing refineries, and land to the east is separated by a public highway (Rosper Road).

3.9.7 Other land to the east of Rosper Road (within Phillips 66's ownership) was considered for a central CO_2 compression facility that would serve both of the Proposed Developments. This was discounted due to the complexities of operating this facility with differing export profiles of CO_2 from the Refinery and CHP Plant. This land was also allocated for the Gigastack project to supply green hydrogen to the Humber Refinery, which is another opportunity to further decarbonise and reduce emissions from the Refinery (see Chapter 18: Cumulative and Combined Effects which includes consideration of cumulative effects from the Proposed Developments and Gigastack).

3.9.8 For this reason, alternative sites are not considered appropriate.

Alternative Technologies

3.9.9 No alternative technologies to post combustion carbon capture have been identified to reduce the Humber Refinery FCC's emissions by the same or similar level, since this is a refinery process that inherently generates CO_2 emissions (as opposed to resulting from an energy input requirement). Therefore the only option is to capture the CO_2 emissions generated.

3.9.10 Alternative technologies to reduce the VPI Immingham CHP Plant's CO_2 include hydrogen firing. At present there is insufficient hydrogen available for firing the VPI Immingham CHP Plant GT1 and GT2, so carbon capture is the only available option within the project timescales (i.e. completion around the end of 2027).

3.9.11 For this reason, alternative technologies are not considered feasible at this stage within the project timescales.

Alternative Design Options/ Layouts and Design Evolution

3.9.12 Alternative designs options have been explored through the pre-Front End Engineering Design (pre-FEED) process and ongoing FEED process for each of the Proposed Developments.

3.9.13 Decisions taken regarding the concept design of the Proposed Developments have, where relevant and possible, been informed by environmental appraisal and assessment work and by consultation with stakeholders.

Table 3.3: Summary of design evolution for Proposed Phillips 66 Development

Design Aspect	Summary of Options Considered
Cooling technology	Air and water cooling options were considered. Air cooling was selected over water cooling wherever possible to avoid significant increase in water demand given that water resources are already constrained in the region.
Flue gas pre-treatment technology	Use of a direct contact cooler/ quench tower or wet gas scrubber were considered to abate SO_x and cool flue gas prior to carbon capture. It was determined that a direct contact cooler would not sufficiently abate particulates. A wet gas scrubber was selected for flue gas pre-treatment to remove SO_x, and particulates from the flue gas whilst recovering energy to ensure reliable operation of the CO_2 capture plant. SCR and a wet electrostatic precipitator were also selected to abate NOx and reduce aerosols.
Carbon capture technology	Available carbon capture technology licensors were reviewed. Shell was selected as the preferred technology provider for a variety of reasons including design efficiency for CO_2 removal, technical viability, energy efficiency, cost and the fact that the Shell technology has been demonstrated technically at scale and in relevant applications.
Integration with CO_2 transport and storage network	Options to connect into Humber Low Carbon Pipeline and Viking CCS were considered. The Proposed Phillips 66 Development has been designed to allow for connection to either or both of these CO_2 transmission networks, maintaining operational and commercial flexibility.

Table 3.4: Summary of design evolution for Proposed VPI Development

Design Aspect	Summary of Options Considered
Cooling technology	Air and water cooling options were considered. Air cooling was selected over water cooling wherever possible to avoid significant increase in water demand given that water resources are already constrained in the region.
Carbon capture technology	Available carbon capture technology licensors were reviewed. Shell was selected as the preferred technology provider for a variety of reasons including design efficiency for CO_2 removal, technical viability, energy efficiency, cost and the fact that the Shell technology has been demonstrated technically at scale and in relevant applications.
Number of PCC trains	Layouts with two larger or three smaller PCC trains were considered. Two larger trains were selected to reduce the area of land required for the PCC plant.
Integration with CO_2 transport and storage network	Options to connect into Humber Low Carbon Pipeline and Viking CCS were considered. The Proposed VPI Development has been designed to allow for connection to either or both of these CO_2 transmission networks, maintaining operational and commercial flexibility.

3.9.14 To retain flexibility in the design, the maximum (or where relevant, minimum) parameters have been assessed within the differing layout options. As such, this ES represents a reasonable

worst-case assessment of the potential impacts of the Proposed Developments at the current stage of design.

The Do-Nothing Alternative

3.9.15 It is considered that a 'do-nothing' scenario is not appropriate given the established national need for industrial decarbonisation to meet the UK's Net Zero targets (refer to Chapter 5: Policy Context). The carbon capture offered by the Proposed Developments of up to 3.8 million tonnes CO_2 per year would not be realised.

3.9.16 Another key disadvantage of a 'do-nothing' scenario would be the lack of additional investment in the local economy since the Proposed Developments would not be pursued, and this may result in the decline of local industry due to lack of alignment with a net zero pathway. Further, the Proposed Developments aim to form the basis for a potential cluster of projects in the future, with ambitions for both green and blue hydrogen production and further decarbonisation related developments, collectively known as Humber Zero.

3.9.17 For these reasons, the 'do-nothing' scenario is not considered appropriate, although it has been assessed as part of the baseline conditions in the EIA presented in the topic specific chapters of the ES (Chapters 6 – 18 of ES Volume I).

3.10 Conclusions

3.10.1 The Proposed Developments aim to decarbonise the largest industrial area in the Humber region and contributes to the UK Government's objective to achieve Net Zero by 2050, therefore the Proposed Developments are required.

3.10.2 Alternative sites or technologies to that presented in Section 3.3 of this Chapter are not considered appropriate due to the already existing installations and operations to generate power at the Sites and adjacent industries facilitating CO_2 transport into the network.

3.10.3 The form and approach to the Proposed Developments has been identified as above, taking into account potential environmental effects, alongside other factors such as technical and commercial feasibility.

3.11 References

HM Government (2020) Energy White Paper. Available at: https://www.gov.uk/government/publications/energy-white-paper-powering-our-net-zero-future