H2Teesside Project

Environmental Permit Application Reference: [EPR/AP3328SQ/A001]

Land at and in the vicinity of the former Redcar Steel Works site, Redcar and in Stockton-on-Tees, Teesside

Document Reference: Appendix C3 Assessment of Best Available Techniques for Cooling

Environmental Permitting (England and Wales) Regulations 2016

Applicants: H2 Teesside Ltd

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GLOSSARY

Abbreviation	**Description**
Applicant/Operator	H2 Teesside Ltd
ATR	Auto Thermal Reforming
BAT	Best Available Techniques
BAT-AEL	BAT- Associated Emission Level
CCS	Carbon Capture and Storage
CCUS	Carbon Capture, Usage and Storage
CO_2	Carbon dioxide
DCO	Development Consent order
ETP	Effluent Treatment Plant
FEED	Front-End Engineering Design
FID	Final Investment Decision
H_2	Hydrogen (gaseous)
HRA	Habitats Regulations Assessment
LHV	Lower Heating Value
LNR	Local Nature Reserve
MLD	Minimalised Liquid Discharge
NEP	Northern Endurance Partnership
NNR	National nature Reserve
NWL	Northumbrian Water Limited
NZT	Net Zero Teesside
O_2	Oxygen
SPA	Special Protection Area
SPZ	Source Protection Zone
SSSI	Site of Special Scientific Interest
STDC	South Tees Development Corporation
WwTW	Wastewater Treatment Works

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1.0 INTRODUCTION

1.1 Overview

1.1.1 This report has been prepared by AECOM Limited ('AECOM') on behalf of H2 Teesside Ltd ('H2TS') referred to as "the Operator", in support of the application for environmental permit for the proposed Carbon Capture and Storage (CCS) enabled Hydrogen (H_2) Production Facility in the Teesside industrial cluster area in Redcar, Stockton-on-Tees.

1.1.2 The purpose of this report is to demonstrate the proposed Installation will be designed and operated in accordance with indicative best available techniques (BAT) for cooling systems.

1.1.3 The Hydrogen Production Facility (hereafter referred to as the 'Installation) is subject to ongoing technical studies; however, it is expected to comprise an up to 1.2-Gigawatt Thermal (GWth) (Phase 1, 600-Megawatt thermal (MWth) LHV and Phase 2, 600 MWth LHV) Lower Heating Value (LHV) Carbon Capture (CC) enabled Installation . It will be supported by a natural gas supply connection for the supply of natural gas to the Installation, utility connections (including water and electricity) along with pipelines to export the H_2 gas and carbon dioxide (CO_2). The CO_2 captured from the Installation will be transported (via the export/transport pipeline) for secure storage within the Endurance saline aquifer, located 145 kilometres offshore from Teesside, under the North Sea. The Installation is estimated to have a capacity to export approximately 1.27 megatonnes (Mt) of dehydrated and compressed CO_2 per year per phase, i.e. approximately 2.54 Mt/year once both phases are operational (100% utilisation) to NEP for offshore underground storage. No temporary CO_2 storage is required on site.

1.1.4 A high level process flow diagram (Figure 3) for the Installation is provided in Appendix A (Drawings and Plans) to the main supporting statement Document Reference: AP3328SQ-APP-SS).

1.1.5 The proposed Installation will be designed to optimise the capture of carbon from the hydrogen production plant, while minimising emissions and waste generation and maximise energy efficiency. While individual BAT assessments have been prepared to demonstrate application of best available techniques for Blue Hydrogen with Carbon Capture, Large Combustion Plant, Energy Efficiency, Emissions Management and Cooling, the system will be integrated to address effects across the Installation as a whole.

1.1.6 The electrical, steam, steam condensate and water circuits between the hydrogen production and capture plant will be integrated as far as reasonably practicable in order to reduce energy use, as discussed in the Energy Efficiency BAT Assessment (Appendix C4; Document Reference: AP3328SQ-APP-BAT4-EE).

1.1.7 This BAT assessment has been prepared using concept engineering information provided by the Operator related to initial design parameters of the proposed

Installation, available information about the local environment and the existing standards and guidelines presented in published guidance, including:

- Environment Agency: Emerging techniques for hydrogen production with carbon capture (February 2023)[(1)];
- EU Reference Document on the application of Best Available Techniques to Industrial Cooling Systems (December 2001)[(2)]; and
- Environment Agency: Risk assessments for your environmental permit (November 2023)[(3)].

1.1.8 The main application document (Document Reference: AP3328SQ-APP-SS "Supporting Statement") provides an overall view of the permit application.

1.1.9 This document should be read with the Supporting Document (Document Reference: AP3328SQ-APP-SS) which provides a detailed description of the operations to be undertaken at the proposed Installation and how it will be operated in Section 4 of the supporting document.

1.2 Cooling Load Assessment

1.2.1 The cooling circulating load associated with the proposed Installation will be in the order of 120.31 MW (10,362 m^3/hr) per phase, equating to 240.62 MW (20,724 m^3/hr) in total for both phases. Water demand per phase for top up equates to 167 m^3/hr.

1.2.2 The principal cooling loads are associated with the following heat exchangers:

- Syngas cooler E-112004
- Blowdown cooler E-112005
- Lean solution cooler E-08003
- CO_2 cooler E-08005
- CO_2 compression package X1001
  - CO_2 Compression interstage coolers 1-3, E-114002A/B, E-114003A/B, E-114004
  - CO_2 Compressor discharge cooler E-114005
- H_2 Product cooler E-14001A/B
- ASU Cooler, part of package X-120001 [note this may be removed if suitable third party supply of O_2 is identified]
- Solid desiccant cooler, part of Regeneration Cooler E-11001
- Low pressure (LP) blowdown overheads condenser E-701
- Tail gas compressor package J-501A/B

1.2.3 Cooling water (CW) will be supplied by a cooling water tower and is circulated across the plant. There will be losses from the cooling water tower due to evaporation, blowdown, and drift losses. Therefore, partially treated raw water used to supply cooling water makeup. A cooling water dosing package is required to prevent scale and corrosion.

1.2.4 Cooling water blowdown will be sent to the Effluent Treatment Plant (ETP)before sending out the final effluent to battery limit.

1.3 Site Considerations

1.3.1 The proposed Installation will be located within approximately 91 ha of land (known as the 'The Foundry' site) previously within the Redcar steelworks site. The land was specifically used for iron and steel manufacture, together with associated ancillary development. The former steelworks shut in October 2015 and much of the existing infrastructure including industrial buildings, conveyors, tanks, and overhead pipes are either demolished or in the process of being dismantled by the landowner as part of the decommissioning of Redcar Steelworks, to prepare the site for future. A combination of hardstanding, road networks and railway tracks remain, surrounded by informal vegetation (primarily grass, with occasional shrubs and small trees). Prior to construction of the Proposed Installation, the Site will be levelled and appropriately remediated.

1.3.2 The location of the proposed development is discussed in detail in the Environmental Statement (Volume 1, Chapter 6, Need, Alternatives and Design Evolution). In particular, with reference to the location within the South Tees Development Corporation (STDC) site, the selected land plot was identified as the most suitable for the following reasons:

- Process safety considerations;
- Proximity to the east coast and Northern Endurance Partnership (NEP) infrastructure, to enable high pressure CO_2 export to be quickly directed offshore, specifically to the Endurance storage facility;
- Size – ensuring that there is sufficient space for the proposed development, that it is safe for construction, and it has expansion potential;
- Utilising brownfield land where possible;
- Distance from residential areas (with remoteness from residential receptors being preferable);
- Proximity to industrial offtakes that could connect into the H_2 network;
- Proximity to necessary connections including a natural gas network, electricity transmission network, water supply and wastewater management options;
- Minimising environmental/social effects or risks; and
- Discussions with landowners.

1.3.3 Site specific environmental considerations are discussed in Section 4.

2.0 WATER SOURCE AND DISCHARGE CONSIDERATIONS

2.1 Water Supply

2.1.1 The combination of the availability of suitable quality and volume of water influences the selection of BAT for cooling for the proposed Installation.

2.1.2 Raw water for the proposed Installation will be sourced from the existing Northumbrian Water Ltd (NWL) raw water supply and which is abstracted from the River Tees. This is considered as the primary source of water for the Installation.

2.1.3 It is expected that water will be supplied via either:

- the existing NWL raw water supply to the Teesworks site; or
- a new connection to the existing NWL raw water supply either via tie in to NZT infrastructure or the installation of a new connection.

2.1.4 A Raw Water treatment Plant will be used to pre-treat the source water prior to the demineralisation stage and the Demineralisation Plant will be used to treat water supplied to the Hydrogen Production Facility.

2.2 Cooling Water Discharge

2.2.1 Cooling water blowdown will be sent to the neutralisation sump in the Effluent Treatment Plant (ETP) located on the main site.

2.2.2 Wastewater management includes two separate wastewater treatment processes. The first involves the treatment of process condensate from the syngas plant, DAF waste, filtration waste and flare KO drum liquid in the biological treatment plant followed by recirculation to the raw water treatment plant. The second involves treatment of cooling water blowdown, DMW plant rejects and dewatering filtrate in the ETP followed by discharge via the NZT outfall to Tees Bay.

3.0 INSTALLATION COOLING OPTIONS

3.1 Indicative BAT for Blue Hydrogen Production Cooling Systems

3.1.1 BAT for cooling systems is defined in the Industrial Cooling Systems Bref document. This document is referenced in the Environment Agency's Guidance on emerging techniques for hydrogen production with carbon capture.

3.1.2 Indicative BAT for cooling is defined as follows:

"In an integrated approach to cooling an industrial process, both the direct and indirect use of energy are taken into account. In terms of the overall energy efficiency of an installation, the use of a once-through system is BAT, in particular for processes requiring large cooling capacities (e.g. >10MWth). In the case of rivers and/ or estuaries once-through can be acceptable if also:

- *Extension of heat plume in the surface water leaves passage for fish migration;*
- *Cooling water intake is designed aiming at reduced fish entrainment; and*
- *Heat load does not interfere with other users of receiving surface water.*

For power stations, if once-through is not possible, natural draught wet cooling towers are more energy-efficient than other cooling configurations, but application can be restricted because of the visual impact of their overall height."

3.1.3 This preference for considering direct cooling as BAT has been called into question, not least because of the age of the report (2001) but also a number of studies, particularly in the US, suggest that the impact on fish may be greater than previously thought.

3.1.4 The EA's position is understood to be that its preference for direct cooling remains unchanged, with its own work (Evidence Document SC070015/SR3) confirming this to be indicative BAT for estuarine and coastal sites (with a follow-up report on protection of biota within estuarine and coastal waters used for cooling water intake and outfall (Evidence Document SC180004/R1)). However, depending on the local environmental sensitivities, in accordance with EA Technical Guidance, wet, hybrid or air-cooled systems can also be regarded as BAT, subject to an appropriate and site-specific assessment.

3.2 Options Overview

3.2.1 The total cooling duty for the Installation would be circa 120 MWth provided by a single common cooling system.

3.2.2 The Installation will be designed to maximise energy efficiency, including where optimal, integration of steam system, water supply and cooling circuits, in accordance with indicative BAT. This will be carried out during FEED as part of, and following, the technology selections.

3.2.3 The assessment has been made on the basis of continuous operation of the Installation.

3.2.4 There are four main options available to service the cooling duty of the proposed Installation:

- Once-through water cooling;
- Wet cooling tower;
- Hybrid (wet/ dry) cooling tower; and,
- Air-cooled condenser (dry cooling).

3.2.5 These options are considered in more detail below

3.3 Once-Through Cooling

3.3.1 Once-through cooling uses water pumped from controlled waters (such as an estuary, river or other surface water feature) via a large water inlet, directly through a heat exchanger or condenser, after which the heated water is discharged directly back into the surface water. Once through cooling represents one of the most efficient cooling processes due to the low cooling water temperature and the high heat transfer characteristic of water-cooled condensers. However, once-through cooling systems involve significant water use (some 50-100 times more than with cooling towers) and would present a significant impact on the river in terms of both intake volume and thermal impact of discharge.

3.3.2 Once-through systems are affected by the availability of sufficient surface water and the water quality, as well as discharge limitations, for example the effect of the thermal load on the receiving water body and its ecological sensitivity. As all the cooling water used in once-through systems is usually discharged (rather than being recirculated), it undergoes only mechanical screening and coarse filtration to prevent serious damage to downstream equipment, so that there is no change in water chemistry between the circulating water and the source water. Scale deposition of biological fouling is a common issue with once-through cooling systems and if the water is more corrosive (i.e. sea water or estuary water, as in the case of the proposed Installation) the impact on material costs can be significant.

3.3.3 Other environmental considerations include:

- the use of energy for pumping;
- the risk of fish entrainment and need to restrict approach velocity; and
- the use of additives, such as scale treatment, with subsequent discharge to the controlled water.

3.3.4 The Installation will be using raw water supplied by NWL rather than a new abstraction and based on the volumetric flow (to accommodate the discharge temperature requirement) it is considered unviable for once-through cooling water to be supplied via NWL and as such this option has been discounted as additional abstraction would be required.

3.4 Wet Cooling

3.4.1 Wet cooling condenses steam using a (semi) closed circuit of cooling water as the main cooling medium in direct contact with a cooling air flow through the towers. The heat load in the cooling water is removed by evaporation within the cooling towers and the cooled water is recirculated within the system typically via a reservoir (cooling tower basin). A percentage of the cooling water (c.1-2%) is lost through evaporation and drift (entrainment of droplets); blow-down is required to maintain water quality resulting from cycles of concentration. The system level is maintained through make-up water from the abstraction. The Industrial Cooling Systems BRef states that the volume of make-up water required for facilities using an open loop wet cooling system can be 1-5% of that required for similar sized once-through cooling systems.

3.4.2 Cooling water from the steam condenser is pumped to the top of the cooling tower and the water is distributed, by spray, over the cooling tower packing, to maximise the contact with steam flow though the packing.

3.4.3 Drift eliminators are employed at the top of the tower to minimise the entrainment of water droplets within the air flow. The air exiting the tower will be saturated with water, and therefore visible plumes will frequently occur as the warm air mixes with colder atmospheric air causing condensation of the water vapour. The extent of the plume formation is dependent on weather conditions, with colder or more humid air resulting in larger plumes.

3.4.4 The continuous evaporation of the cooling water can result in a concentration of dissolved salts present within the cooling water. To maintain the dissolved solid content to within design parameters of the cooling towers, a small amount of water is removed (purge/blow-down), and make-up water is added to the cooling tower recirculation system to compensate for the volume losses from evaporation and purging (make-up).

3.4.5 Several alternative designs for the water-air evaporative cooling stage can be employed, including:

- natural-draught air flow, which relies on a pressure differential between top and bottom of the tower, generated by the change in density of the air, to induce a draught of air up the tower in a counter-flow to the cooling water; and
- mechanical-draught air flow, which uses mechanically generated air flow using fans either at the top (induced-draught) or bottom (forced draught) of the tower; within these systems the air flow can be perpendicular to the water flow (crosscurrent) or in the opposite direction to the water flow (counter-current).

Natural Draught Towers

3.4.6 Natural draught towers are made from reinforced concrete and are high capital cost; they may be 80-150m in height and can emit continuous visible plumes when operational and therefore can present significant visual impact, as well as the potential for generating large visible plumes, plume grounding and the risk of icing of roads during certain weather conditions. Natural draught towers are best suited for areas of high relative humidity; therefore, natural draught towers are considered to not be efficient for areas such as that for the location of the proposed Installation, having a design relative humidity of 67.5%. Natural draught towers are not considered to be appropriate for the Installation due to efficiency issues arising from typically lower relative air humidity, limited turndown and flexibility, cost effectiveness for the cooling duty required and the visual impact of water plumes and the towers themselves. The use of natural draught cooling towers has therefore been discounted from this assessment. Their use, generally, is rare in the UK of recent times.

Mechanical Draught Towers

3.4.7 Mechanical draught towers are typically smaller than natural draught towers, and therefore the capital investment is lower; Mechanical draught systems also produce visible plumes, albeit at lower tower exit height than for natural draught systems. The impacts from visible plumes depend on the proximity and sight-lines of nearby receptors. Their disadvantage compared to natural draught is that the require motorised fans to assist the air flow, which require use of auxiliary power and result in significant noise emissions.

3.4.8 Mechanical draught cooling towers can be saline or non-saline. In both cases, the water intake system needs to be protected from organic growth to prevent blockages. Disinfection processes (e.g. chlorination) can be employed, although this has a potential environmental impact from the discharge; alternatively, thermal treatment can be employed although this is more complicated to operate and may affect thermal efficiency of the Installation. Saline cooling towers have the added disadvantage that the exchanger equipment materials need to be of higher specification and therefore this increases the equipment cost.

3.4.9 It is known that there is sufficient (non-saline) water supply available for application of this cooling technology at the site from the NWL supply.

3.4.10 The assessment has therefore included consideration of a wet cooling system for the proposed Installation with mechanical draught cooling towers, using raw water supplied from NWL is a viable option.

3.5 Air Cooled Condenser

3.5.1 Dry air cooling is the direct condensation of the steam by a cooling flow of air via a bank of condensing heat exchangers. 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. The steam is condensed in the heat exchangers and is then recovered as condensate to be reused in the steam cycle.

3.5.2 ACCs require no off-site infrastructure and rely solely on the supply of electrical energy to operate the fans; however this can be a very considerable auxiliary load significantly reducing the overall plant efficiency.

3.5.3 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 arrangement is the least favourable arrangement from an efficiency point of view; this is particularly marked at higher ambient air temperatures. These systems are best suited for locations with a consistently high relative humidity, with efficiency decreasing with lower relative humidity levels, as is likely at the proposed Installation location.

3.5.4 ACCs have the added disadvantage of the noise generated by the fans and the larger footprint required to achieve the necessary level of cooling.

3.5.5 However, ACCs offer benefits in other areas such as avoiding the environmental impacts associated with water abstraction and discharge as well as the construction effects of the associated infrastructure; and heat is discharged directly to the air without the generation of visible plumes created by wet methods.

3.5.6 Early pre-FEED design compared water and air cooling options and indicated that ACC could potentially offer around 13% saving in CAPEX and 18% savings in OPEX over the water cooled option for the syngas cooler and that CAPEX/OPEX for the CO2 interstage cooler was similar for both options.

3.5.7 The assessment has therefore included consideration of an ACC system for the proposed Installation as a potentially viable option.

3.6 Hybrid Cooling

3.6.1 Hybrid cooling (also known as plume-abated mechanical draught cooling) also uses water as the main cooling medium. The heat load in the cooling water is removed in the hybrid cooling towers by a combination of dry air cooling, and evaporative cooling.

3.6.2 The cooling water is first dry-cooled, by passing through tube banks in the hybrid cooling towers over which air is drawn by forced draught fans; this reduces the evaporative cooling load in the wet stage. The cooling water then passes to a wet cooling stage where it is sprayed over packed bed elements, to provide an extended, and therefore more efficient, air/ water contact surface area. In the wet cooling stage, the water is cooled by two effects: the direct contact of the cold air flow with the water, and the cooling effect of the evaporation of a small proportion of the water.

3.6.3 The cooling water demand for a hybrid cooling system at the site could be sourced from the NWL raw water supply similar to that for wet cooling towers, as discussed in Section 3.4 above.

3.6.4 This method of cooling is more efficient than ACC; it benefits from the more efficient water-cooling heat exchange characteristics but still relies on the ambient air conditions to achieve some cooling. Hybrid tower systems are comparable in size to mechanical draught cooling towers. However, the additional fans result in a higher associated auxiliary power load and greater noise generation than fully wet cooling methods.

3.6.5 The hybrid tower system also requires make-up water to compensate the losses through evaporation and the purge of concentrated salts in the recirculated water; however, the water consumption is typically c.25% of that for wet cooling systems. The Industrial Cooling Systems BRef states that the consumption of water for an open hybrid tower is typically around 0.5m3/h/MWth.

3.6.6 Hybrid cooling towers can, however, still produce visible plumes of water vapour under certain weather conditions, in particular during cold or humid weather, however the incidence of such plumes is significantly less than for fully wet-cooling systems as the dry-cooled stage reduces the evaporation requirement, and the evaporated water is heated (thus increasing the saturated vapour pressure of water in the emission from the hybrid tower) as the vapour passes across the dry cooled section.

3.6.7 Hybrid cooling costs significantly more, and also uses more power thereby lowering the overall plant efficiency. They are, therefore, only considered to be the most suitable cooling option where plume-abatement is considered important.

3.6.8 The assessment has concluded that given the cost implications and impact on plant efficiency that hybrid cooling is not an option and was discounted from further assessment.

3.7 Further Evaluation of Air Cooled and Water Cooled Options

3.7.1 Each cooler on site was further assessed for the use of either water or air as a cooling medium using standard qualitative/semi-qualitative criteria.

3.7.2 The key values and trade-offs for selecting water cooling instead of air cooling are summarised in Table 3-1 below.

Table 3-1: Summary of reasons for cooling option selection

Decision criteria	Value / Trade-off	Impact
Regulatory compliance/complexity	Value	Air cooling has a negative impact due to increased noise and vibration. Vibration and noise impact to ecological systems. Required threshold at the northern boundary would be 60dB (conservative) or 70dB base case based on the NZT precedence. 60dB can be achieved providing the highest noise sources are maintained at the minimum 20m distance from the Northern Site boundary, which would lead to site layout restrictions for ACC.
Complexity (Physical constraints/ space/ maintenance/ access)	Value	Water cooling had a lower unit standard design, lower number of moving parts, easier maintainability/ access.

Decision criteria	Value / Trade-off	Impact
Social/reputational	Value	Water cooling has a more positive social and reputational impact as it is less noisy and less visible to off-site – impact on residential receptors reduced.
Reliability and resilience to future operations	Value	Water cooling has more reliable operations during periods of heavy downpour, as using air cooling can result in significant process control challenges.
Energy consumption	Neutral	Similar energy consumption for both options
Health and safety considerations	Value	Water coolers had a lower human factor risk (inherently safer from a maintainability point of view). Also toxic gas release directly to atmosphere eliminated in CO_2 coolers.
Key biodiversity features and impact on species	Value	Water cooling had a lower impact on species due to less noise/vibration. Less layout restrictions would also exist as noise will not be limiting factor.
Water Consumption	Trade-off	Water cooling results in increased water consumption as a continuous supply is required to address evaporative losses.
Protected area (water contamination and nutrient neutrality)	Trade-off	Nearby protected areas (evaporative losses), increased cooling tower blowdown to waste water, but impact to protected areas deemed low.
CAPEX/OPEX	Neutral	Based on a contractor assessment undertaken fortwo coolers, it is assumed that CAPEX and OPEX cost difference for the cooling medium choices will be minimal for all the coolers.

3.7.3 Cooling water was selected as the cooling medium to be used in all coolers, due to various criteria, importantly the UK legislative limits on noise and low ambient noise limits in this vicinity, especially related to residential receptors. The only exception is the regeneration cooler, where using cooling water is not suitable due to the inlet process temperature being >150 °C and would result in the boiling of cooling water.

4.0 EXISTING ENVIRONMENT

4.1.1 This section describes the environmental context for the proposed installation, in particular the local environment with the potential to be impacted by the cooling options under consideration.

4.1.2 A number of environmental receptors have been identified in the vicinity of the site. All distances are given as the shortest distance between the receptor and the closest point of the proposed Installation boundary.

4.2 Residential Receptors

4.2.1 Nearby residential communities include the towns of:

- Dormanstown (approximately 1.3 km south-east); and
- Redcar (approximately 2.6 km east),

4.2.2 The sensitivity of these receptors to visible impacts, such as visible plumes and buildings and structures, is considered to be relatively low given the historic use of the site as a steelworks, and the prevalence of industrial land use in the surrounding area.

4.3 Ecological Receptors

4.3.1 The Teesmouth and Cleveland Coast, located immediately north of the site, is a statutory site designated as SSSI, Ramsar and a Special Protection Area (SPA). The site includes a range of coastal habitats (sand- and mud-flats, rocky shore, saltmarsh, freshwater marsh and sand dunes) on and around the Tees Estuary.

4.3.2 The River Tees is approximately 0.9 km to the west of the Site, whilst the Tees Bay is approximately 0.68 km to the north of the Site. The River Tees is tidal at this location and forms part of the Teesmouth and Cleveland Coast SSSI. The Tees river and estuary is an important water body for fish species which make seasonal migrations between the sea and riverine environment, including salmon, sea trout, European eel, river lamprey and sea lamprey.

4.4 Climate Change Considerations

4.4.1 Considerations include:

4.4.2 **Effects of air temperature change** – The exchange of heat is driven by the temperature difference between the 'hot' and 'cold' side of a heat exchanger. Therefore, the efficiency of any cooling system is dependent on the temperature of the cooling medium. For air-cooled systems, the dry bulb temperature, which is higher than the wet-bulb temperature, defines the minimum temperature for cooling.

4.4.3 In effect this means that during hot, dry weather, air-cooled systems are much more limited in the cooling performance achievable compared with wet-cooled systems and are affected more generally by fluctuations in air temperature than wet systems. Since water has been selected as the cooling medium, this impact on cooling performance is minimised.

4.4.4 **Effects of sea-water temperature change** – As outlined above, the efficiency of any cooling system is dependent on the temperature of the cooling medium. For wet (evaporative) cooling systems, the wet bulb temperature (that is dependent on the measured atmospheric temperature, relative humidity and air pressure) influences the rate of evaporation as this is the theoretical lowest temperature to which water can be cooled by evaporation.

4.4.5 In addition, the difference between air and water temperatures in winter further reduces any efficiency gains; most efficiency gains are seen in summer months when the water temperature is relatively low when compared to ambient air. Development of the water basis of design has indicated that the NWL raw water incoming supply will have a minimum temperature of 0.2^{O}C and maximum temperature of 22.3^{O}C. A review of the Met Office Climate datasets for Northeast England for the period 1884 to 2023 has indicated that the ambient air ranges from a minimum of -5.5^{o}C in winter to a maximum of 22.3^{o}C in summer months.

4.5 Key Environmental Considerations

4.5.1 Of the identified receptors, the internationally designated ecological conservation area is considered to be the most sensitive to impacts from the cooling options.

4.5.2 Potentially significant impacts would be:

- the abstraction of water, with mitigation required to avoid entrainment of aquatic organisms;
- impacts on water chemistry and biodiversity from the discharge of water with thermal plume and potential water treatment chemicals;
- noise impacts from fans with potential disturbance of birdlife; and
- temporary construction impacts from installation of additional discharge pipework.

Noise

4.5.3 Noise impacts on local residential receptors from any of the cooling options are considered to be of lower importance because of the distance to receptors, and the existing industrial environment in which the proposed development would be located. It is considered that such impacts could be adequately mitigated for with appropriate selection of equipment and screening measures as necessary. Noise impacts of cooling have been minimised by the selection of water cooling instead of air cooling.

Discharge

4.5.4

4.5.5 Wastewater management includes two separate wastewater treatment processes. The first involves the treatment of process condensate from the syngas plant, DAF waste, filtration waste and flare KO drum liquid in the biological treatment plant followed by recirculation to the raw water treatment plant. The second involves treatment of cooling water blowdown, DMW plant rejects and dewatering filtrate in the ETP followed by discharge via the NZT outfall to Tees Bay.

4.5.6 .

4.5.7 Because the water discharge is via the NZT outfall it is envisaged that the following discharge conditions would need to be met, based on the sensitivity of the receiving water, and nature of the outfall (including its distance from shore, depth, use of diffusers etc). Conservatively it is assumed that these conditions would minimise the risk of significant impacts on the receiving water:

a) ***Specific temperature range for the discharge*** – It is expected that the cooling discharge would be within specific temperature range to minimise potentially significant thermal plume effects from the discharge. The temperature of the cooling discharge would be dependent on the mixing zone and the extent of the thermal plume which could have seasonal variation. The acceptable temperature range of the cooling discharge has been modelled and 10 °C limit is calculated to ensure no adverse impact on the receiving waters for smaller flows associated with cooling tower blow-down discharges. Thermal plume modelling of a wet tower cooling water (blow-down) discharge from the NZT outfall has been undertaken as part of the Environmental Statement this concluded that no significant effects on the designated ecological receptor occur as a result of that thermal plume and that the mixing zone is sufficiently small.

b) ***Water quality requirements*** – It is anticipated that, as a minimum, the following limitations will be placed on any direct discharges to controlled waters;

   - there will be limits on the excess free chlorine in the discharge;
   - the heat input from the discharge to the surface waters will need to be within a specific limit reflecting the temperature range and mixing zone in the receiving water;
   - addition of screens to minimise fish impingement and entrainment.

   In addition the basis of design has identified further relevant water quality requirements for example for nitrates, which the proposed Installation will adhere to

4.5.8 Utilisation of the NZT outfall if the discharge option is chosen, means that the temporary impacts of construction can be avoided by removing the need to construct an additional discharge point for this Installation.

Abstraction

4.5.9 Based on the concept engineering design for the proposed Installation, the predicted water demand is 120.31 MW (10,362 m^3/hr) per phase, equating to 240.62 MW (20,724 m^3/hr) in total for both phases.

4.5.10 Water will be sourced from the existing NWL raw water supply and will therefore avoid the need for new abstraction.

4.5.11 Based on the volumetric flow (to accommodate the discharge temperature requirement) it is considered unviable for once-through cooling water to be supplied via NWL.

5.0 COSTS AND BENEFITS OF THE COOLING OPTIONS

5.1.1 As indicated in Section 4.2, the capital expenditure (CAPEX) and operational expenditure (OPEX) cost difference between air cooling and water cooling will be minimal for all the coolers.

5.1.2 According to the criteria described in Table 3-1, water cooling therefore demonstrates more benefits than air cooling at a similar cost. This indicates that the best available cooling technique has been selected.

6.0 ASSESSMENT AGAINST BREF FOR INDUSTRIAL COOLING SYSTEMS

Table 6.1 BAT Assessment Against BRef for Industrial Cooling Systems

BAT No.	BATC Requirements	Demonstration of BAT	Operating to BAT?
1	**BAT 1 Reduction of energy consumption** It is BAT in the design phase of a cooling system: • To reduce resistance to water and airflow • To apply high efficiency/low energy equipment • To reduce the amount of energy demanding equipment (Annex XI.8.1) • To apply optimised cooling water treatment in once-through systems and wet cooling towers to keep surfaces clean and avoid scaling, fouling and corrosion. For each individual case a combination of the above-mentioned factors should lead to the lowest attainable energy consumption to operate a cooling system. Concerning BAT a number of techniques/approaches have been identified. In an integrated approach to cooling an industrial process, both the direct and indirect use of energy are taken into account. In terms of the overall energy efficiency of an installation, the use of a once-through systems is BAT, in particular for processes requiring large cooling capacities (e.g. > 10 MWth). In the case of rivers and/or estuaries once-through can be acceptable if also: • extension of heat plume in the surface water leaves passage for fish migration; • cooling water intake is designed aiming at reduced fish entrainment;	The following techniques will be used to reduce energy consumption: • Modulation of air/ water flow • Optimised water treatment and pipe surface treatment to avoid scaling, fouling and corrosion. • Applying pumping heads and fans with reduced energy consumption • Regular maintenance The Operator will be using an evaporative cooling tower as the cooling water system which has similar energy consumption as the air-cooled system. See section 3 above for the comparison between air and water cooled systems. Cooling water comes form NWL and is pre-screened to reduce fish entrainment.	Yes

BAT No.	BATC Requirements	Demonstration of BAT	Operating to BAT?
	• heat load does not interfere with other users of receiving surface water. For power stations, if once-through is not possible, natural draught wet cooling towers are most energy-efficient than other cooling configurations, but application can be restricted because of the visual impact of their overall height.		
2	**BAT 2 Reduction of water requirements** For new systems the following statements can be made: • In the light of the overall energy balance, cooling with water is most efficient; • For new installations a site should be selected for the availability of sufficient quantities of (surface) water in the case of large cooling water demand; • The cooling demand should be reduced by optimising heat reuse; • For new installations a site should be selected for the availability of an adequate receiving water, particularly in case of large cooling water discharges; • Where water availability is limited, a technology should be chosen that enables different modes of operation requiring less water for achieving the required cooling capacity at all times; • In all cases recirculating cooling is an option, but this needs careful balancing with other factors, such as the required water conditioning and a lower overall Energy efficiency. For existing water cooling systems, increasing heat reuse and improving operation of the system can reduce the required amount of cooling water. In the case of rivers with limited availability of surface water, a change from a once-through	The proposed cooling system is an evaporative cooler which uses water for cooling and in light of the energy balance will be the most efficient. Water supply will be from a non-potable source thus protecting groundwater and potable supplies. The peak demand for water top up in the cooling system will be 167 m^3/hr per phase and the techniques used at the Installation for reducing water requirements will include: • Optimisation of heat reuse to reduce the need of cooling. • Using an open loop water recirculation system. • Optimization of cycles of concentration. • Installation of a water treatment package to facilitate reuse of blowdown water where possible with discharge of final treated effluent to NZT outfall.	Yes

BAT No.	BATC Requirements	Demonstration of BAT	Operating to BAT?
	system to a recirculating cooling systems is a technological option and may be considered BAT. For power stations with large cooling capacities, this is generally considered as a cost-intensive exercise requiring a new construction. Space requirements must be taken into account.		
3	**BAT 3 Reduction of entrainment of organisms** The adaptation of water intake devices to lower the entrainment of fish and other organisms is highly complex and site-specific. Changes to an existing water intake are possible but costly. From the applied or tested fish protection or repulsive technologies, no particular techniques can yet be identified as BAT. The local situation will determine which fish protection or repulsive technique will be BAT. Some general applied strategies in design and position of the intake can be considered as BAT, but these are particularly valid for new systems. On the application of sieves it should be noted that costs of disposal of the resulting organic waste collected from the sieves can be considerable.	The site is not using once through cooling and water supply is from NWL raw water, so this does not apply.	N/A
4	**BAT 4 Reduction of emissions to water** **a) approach to reduce heat emissions** Whether heat emissions into the surface water will have an environmental impact strongly depends on the local conditions. Such site conditions have been described, but do not lead to a conclusion on BAT in general terms. Where, in practice, limits to heat discharge were applicable, the solution was to change from once-through technology to open recirculating cooling (open wet cooling tower). From the available information, and considering all possible aspects, care must be taken in concluding that this can be qualified as BAT. It would need to balance the penalty increase in overall energy efficiency of applying a wet cooling tower (Chapter 3.2) against the effect of reduced environmental impact of reduced	To limit heat discharge, the system will be an open recirculating cooling system instead of once through. Cooler blowdown waters will be directed to the effluent treatment plant to facilitate reuse where possible followed by discharge of final treated effluent via the NZT outfall, the discharge will be limited to 10 °C which has been assessed as being acceptable.	Yes

BAT No.	BATC Requirements	Demonstration of BAT	Operating to BAT?
	heat discharge. In a fully integrated assessment at the level of a river catchment, this could for example include the raised overall efficiency levels of other processes using the same, but now colder, water source, which becomes available because there is no longer a large warm water discharge into it. Where the measures generally aim at reducing the ΔT of the discharged cooling water, a few conclusions on BAT can be drawn. Pre-cooling (Annex XII) has been applied for large power plants where the specific situation requires this, e.g. to avoid raised temperature of the intake water. Discharges will have to be limited with reference to the constraints of the requirements of Directive 78/659/EEC for fresh water sources. The criteria are summarised in Table 3.6. Reference is made to a provision in Article 11 of this directive regarding derogation of the requirements in certain circumstances		
	b) approach to reduce chemical emissions to water Measures should be taken in the design phase of wet cooling system using the following order of approach: • identify process conditions (pressure, T, corrosiveness of substance), • identify chemical characteristics of cooling water source, • select the appropriate material for heat exchanger combining both process conditions and cooling water characteristics, • select the appropriate material for other parts of the cooling system, • identify operational requirements of the cooling system, • select feasible cooling water treatment (chemical composition) using less hazardous chemicals or	The following design and maintenance techniques for reduction of chemical emissions to water will be used at the facility: • Cooling system design will be optimised taking into consideration process conditions and the expected chemical characteristics of the NWL raw water supply. • During operation, monitoring the corrosive properties within the process and cooling water to optimise the additive selection and reduce use of hazardous chemicals where possible. • Control water velocity to reduce deposition (fouling) in condensers and heat exchangers • Use debris filters to protect the heat exchangers where clogging is a risk • Monitoring and control of cooling water chemistry to reduce additive application	

BAT No.	BATC Requirements	Demonstration of BAT	Operating to BAT?
	chemicals that have lower potential for impact on the environment (Section 3.4.5, Annex VI and VIII) • apply the biocide selection scheme (Chapter 3, Figure 3.2) and • optimise dosage regime by monitoring of cooling water and systems conditions. This approach intends to reduce the need for cooling water treatment in the first place. For existing systems technological changes or changes to the equipment are difficult and generally cost-intensive. Focus should be on the operation of the systems using monitoring linked to optimized dosage. A few examples of techniques with good performances have been identified. They are generally applicable for certain categories of systems; they are considered cost effective and do not need large changes to the cooling installation. After reducing the sensitivity of the cooling system to fouling and corrosion, treatment may still be needed to maintain an efficient heat exchange. Selecting cooling water additives less harmful to the aquatic environment and to applying them in the most efficient way is then the next step. With respect to the selection of chemicals, it has been concluded that a ranking of treatments and the chemicals of which they are composed is difficult if not impossible to carry out in a general way and would be unlikely to lead to BAT conclusions. Due to the large variation in conditions and treatments only a site-by-site assessment will lead to the appropriate solution. Chapter 4 130 Industrial Cooling Systems Such an assessment and its constituent parts could represent an approach that can be considered BAT.		
5	**BAT 5 Reduction of emissions to air** Comparatively, air emissions from cooling towers have not been given much attention, except for the effects of plume formation. From some reported data it is concluded that levels	Techniques to be used at the Installation for reductions of emissions to air include: • use techniques to avoid plume formation	Yes

BAT No.	BATC Requirements	Demonstration of BAT	Operating to BAT?
	are generally low but that these emissions should not be neglected. Lowering concentration levels in the circulating cooling water will obviously affect the potential emission of substances in the plume. Some general recommendations can be made which have a BAT-character.	• designing and positioning tower outlet to avoid intake of air through air conditioning systems and affecting air quality • reduce drift loss by applying drift eliminators	
6	**BAT 6 Reduction of noise emissions** Noise emissions have local impact. Noise emissions of cooling installations are part of the total noise emissions from the site. A number of primary and secondary measures have been identified that can be applied to reduce noise emissions where necessary. The primary measures change the sound power level of the source, where the secondary measures reduce the emitted noise level. The secondary measures in particular will lead to pressure loss, which has to be compensated by extra energy input, which reduces overall energy efficiency of the cooling system. The ultimate choice for a noise abatement technique will be an individual matter, as will the resulting associated performance level. The following measures and minimum reduction levels are considered as BAT.	The design of the cooling system is subject to FEED and based on the noise assessment, consideration will be given to: • selection of low noise fans; • Optimising the sizing of the fan coolers; • Using of anti-vibration supports and interconnections for the equipment. • Locating equipment to provide screening by other buildings and structures or orientating fans and air inlets away from sensitive receptors.	Yes
7	**BAT 7 Reduction of risk of leakage** To reduce the risk of leakage, attention must be paid to the design of the heat exchanger, the hazardousness of the process substances and the cooling configuration. The following general measures to reduce the occurrence of leakages can be applied: • select material for equipment of wet cooling systems according to the applied water quality. • operate the system according to its design, • if cooling water treatment is needed, select the right cooling water treatment programme,	To reduce the risk of leakage, the Installation will: • Select the equipment material based on the expected chemical characteristics of the NWL raw water supply. • Implement effective planned preventative maintenance and monitor the performance of the heat exchanger for signs of deterioration. • During operation, monitor the corrosive properties within the process and cooling water to optimise the additive addition to maintain water quality and reduce the risk of corrosive conditions occurring.	Yes

BAT No.	BATC Requirements	Demonstration of BAT	Operating to BAT?
	• monitor leakage in cooling water discharge in recirculating wet cooling systems by analysing the blowdown.		
8	**BAT 8 Reduction of biological risk** To reduce the biological risk due to cooling systems operation, it is important to control temperature, maintain the system on a regular basis and avoid scale and corrosion. All measures are more or less within the good maintenance practice that would apply to a recirculating wet cooling system in general. The more critical moments are start-up periods, where systems' operation is not optimal, and standstill for repair or maintenance. For new towers consideration must be given to design and position with respect to surrounding sensitive objects, such as hospitals, schools and accommodation for elderly people.	To reduce biological risk as a wet recirculating cooling system, the Installation will demonstrate good maintenance practices and take the following primary approaches: • Reduce light energy reaching the cooling water to reduce algae formation • Avoid stagnant zones(design) and apply optimised chemical treatment to reduce biological growth • A combination of mechanical and chemical cleaning after outbreak (e.g. legionella) • Periodic monitoring of pathogens in the cooling systems to control the pathogens To reduce the risk of wet cooling towers to personnel, the operators will wear nose and mouth protection (P3-mask) when entering a wet cooling tower. The proposed Installation will follow Approved Code of Practice (ACoP) L8 and GH S274 guidelines and will have a competent person appointed at site to manage the risk of legionella. Water will be treated to municipal standard.	Yes

7.0 CONCLUSION

7.1.1 Although once-through cooling using estuarine water is usually identified as indicative BAT in published guidance, the specific geographical and technical conditions (including the carbon capture elements) for the proposed Installation, as outlined previously, lead to the conclusion that once-through cooling does not necessarily represent BAT for this Installation, because:

- the increased volumetric flow required could not be met from the NWL raw water supply and additional abstraction would be needed and the associated environmental effects of the additional water abstraction and thermal plume discharge are significant; and
- the costs and environmental effects outweigh the potential efficiency benefits.

7.1.2 The use of hybrid (plume abated) cooling towers would be indicative BAT if visible plume impacts were a material consideration. However, the site location is not considered to be particularly sensitive to visual impacts from thermal plumes given the industrial landscape and the distances to sensitive receptors and therefore mechanical draught cooling towers are considered to represent BAT for the proposed Installation.

7.1.3 ACC was discounted as representing BAT primarily due to significant noise and vibration impact on sensitive receptors and associated restrictions on plant layout. ACC also had higher complexity and lower reliability than wet cooling.

7.1.4 The use of wet cooling towers, using raw (non-saline) water sourced from NWL represents BAT for the proposed Installation for the following principal reasons:

- Less vibrating and noise impact to ecological systems and residential receptors than alternatives;
- Lower complexity and higher reliability than alternatives;
- Water requirements can be met from the NWL supply without the need for additional abstraction; and
- Lower human factor risk than alternatives.

8.0 REFERENCES

1. Environment Agency, February 2023, Hydrogen Production With Carbon Capture: Emerging Techniques.
2. European Commission, December 2001, Reference Document on the application of Best Available Techniques to Industrial Cooling Systems.
3. Environment Agency, November 2023, Risk assessments for your environmental permit.