Environmental Capacity for Industrial Clusters

Humber Pathfinder Project

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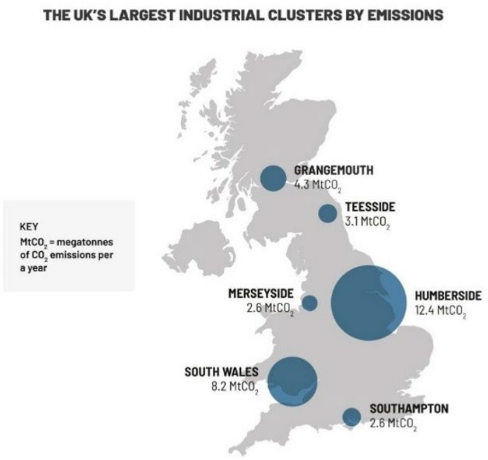
Contents

1. Executive Summary

The climate is changing, we are already feeling the impacts of higher levels of greenhouse gases in the atmosphere. We must both limit climate impacts through rapid decarbonisation and adapt to this new reality. This report provides a glimpse into our net zero future - a vision of what the limitations of the environment and adapting to climate change could look like for industry in a decarbonising industrial cluster.

Global temperatures will soon be teetering on the edge of +1.5° C, with +2° C in sight. The Government has set a target of two low carbon industrial clusters deploying carbon capture and storage by mid 2020s and a minimum of four by 2030. This offers a unique opportunity to couple economic growth with decarbonisation in industrial heartlands, by using new and existing infrastructure to decarbonise industry and generate cleaner energy. These new processes will need to be deployed rapidly at scale, using resources such as water.



This report reviews the water impacts of decarbonising industry while adapting to the limits of the environment in one location in advance of planning and environmental permitting. We've chosen the Humber Industrial Cluster due to its contribution of 12.4Mt to the UK's 33.2Mt total annual industrial carbon dioxide emissions. It includes the highest number of current projects of approximately twelve, all with the potential to use water.

The report develops and tests a collaborative approach to explore the needs of industry and impacts on the water environment of the proposed technologies. We worked with local and national Environment Agency specialists, and key industrial and place maker stakeholders. Work includes a literature review, a targeted stakeholder engagement exercise alongside consideration of known local environmental limits, climate projections and potential mitigation. In doing so the project trials an approach to support deployment of low and zero carbon technologies in all industrial clusters.

The current supply-demand balance is under significant pressure from population growth and climate change in the east, in contrast to a surplus of water in the north of the Humber region. Current water consumption for industry in the region is 204Ml/day before the technologies required to decarbonise are deployed.

Summers in the Humber region are drier compared to a decade ago. The latest UK Climate Projections show that by 2050, the annual average daily temperature will increase between 2-5°C, this results in a corresponding increase in the temperature of rivers with knock on impacts of lower river flows and groundwater recharge.

Water quality in the region is already impacted by multiple factors including diffuse pollution from agriculture, storm foul sewer discharges, and cumulative industrial emissions. As a result, water bodies north and south of the Humber are given the ecological status of 'moderate' indicating a change from natural conditions due to human activity, indicating that improvement is needed.

Looking to the future, the latest UK Climate Change Projections (UKCP18, Met Office, 2018) indicate warmer wetter winters and hotter drier summers in the years to come. Rainfall in the east of England is set to reduce by 34% in summer (Adaptation to climate change risk assessment worksheets for river basin districts, EA, 2019) increasing the frequency of drought conditions and low flows in rivers by 2050. This will impact on the water available and quality of water in the Humber for all users.

Water is a critical resource for industry for process and cooling. Industry in the South of the Humber will require a significant increase in water use between 2025 and 2050 more than 181Ml/day on a worst-case basis, (The Emerging Water Resources Regional Plan for Eastern England, WRE 2022) an increase of 160%. In the north of the Humber the water required for industry is forecast to be 119Ml/day (Water Resources North: Emerging plan for consultation WReN 2022), an increase of only 12%. Whilst there may be some surplus in the North of the Humber region the South is at capacity.

The technologies that will contribute to this consumption include carbon capture, and hydrogen production. A typical blue hydrogen production plant would use 12.6 litres of water to produce 1kg of hydrogen, whereas a green hydrogen plant would use 30 litres per kg of hydrogen.

For a typical carbon capture plant retrospectively fitted to a power station with once through water cooling, the amount of water required could be an additional $98Mm^3$/year. One carbon capture proposal on the Humber will need $8.3Mm^3$ of water to capture 3.3Mt of carbon dioxide. Although, these figures don't assume that water is taken from one source, they show the water intensity of these projects.

The key findings of this project are:

1. **The Humber environment is already constrained by climate change impacts.** Climate change impact modelling is telling us that average rainfall totals in summer have dropped since 2010 resulting in lower river flows and a reduced groundwater recharge season, caused by higher temperatures. Rivers are warming, the ambient temperature of the Humber has increased by 2^oC in the last half of the 20^{th} Century increasing pressure on the aquatic environment.

2. **Water is a limiting factor - Current plans for low and zero carbon technologies are not consistent with current and future challenges to water in the Humber.** Climate change impacts and heavy abstraction means there is no water available for new abstractions on the South Humber bank, finding an extra 181Ml/day for industry will be a significant challenge between now and 2050.

3. **We need to innovate and reduce water use - Water demand must change if the assumptions about water use and impacts on water quality from the technologies proposed are correct.**

   Water use will be the primary limiting factor for water intensive technologies on the South Humber bank. Technologies must be flexible and incorporate multiple water sources, e.g., transfers between regions, on-site storage, and resilience options, into their design. Government should consider the role of research and innovation programmes in driving the development of technologies that capture carbon whilst minimising water use.

   Water efficiency must be prioritised for process and cooling water at the concept development stage. Emphasis must be placed on researching the use and security of supply of water. Water quality must be considered alongside water use.

4. **Collaboration is key - There needs to be an effective forum to explore environmental impacts and limits of low and zero carbon industrial clusters at the local level.**

    Early engagement and exchange of information with industry is essential to enable us to effectively support the deployment of low and zero carbon technologies. Regulators will make site-based decisions on water resources and quality through planning and permitting but this may be too late to make strategic and cohesive cluster-scale decisions. We know that for low carbon industrial clusters to be a success we need government, regulators and industry to collaborate at the cluster scale, and at early stages of deployment. This means we need more explicit collaboration at the local level to explore environmental impacts and limits of low carbon industrial clusters. 94% of industry stakeholders 75% of whom are intensive water users, when engaged didn't respond limiting the detail we needed to make an informed assessment of water needs and impacts on water quality. Without early insight into project development, we are unable to understand the full environmental capacity and potential challenges until a permit is determined.

The project demonstrates that there is a need for a holistic, consistent approach to understand and plan for environmental capacity. We recommend that the work continue, to strengthen, extend and build on the approach we have employed in the Humber. Continuation would allow us to further identify limits that the current and future environment will present beyond water, to explore opportunities for environmental enhancement in industrial cluster developments via further engagement with stakeholders. This work will assist decision makers and industry (at the earliest opportunity) and avoid costly delays in technology deployment.

2. Background

Low carbon technologies pose new risks to the environment, particularly emerging technologies such as carbon capture, and hydrogen production. The environmental capacity and risks related to them are the subject of this report. This includes air quality impacts, water use, water quality impacts, and flood risk, which pose a challenge to Government's intended target of deploying low and zero carbon technologies this decade.

Carbon capture and hydrogen production facilities proposed by various projects will need to apply for and gain the appropriate authorisations to develop and operate. Permit applications will need to demonstrate that potential environmental impacts have been considered and suitably addressed. Policy makers need to understand the extent to which these impacts will pose a challenge. They will need to appreciate how industry and key stakeholders are preparing to address them.

This project developed and trialled an approach for early identification and mitigation of environmental impacts in the Humber Industrial Cluster before environmental permit applications are submitted. With this proactive view of environmental capacity, focused on water use and water quality, we can help Government minimise deployment delays and risks to industrial growth, communities, and the environment. Through our engagement work with stakeholders in the Humber Industrial Cluster, we may also identify opportunities for the wider environment, public health, resilience, the economy and levelling up.

Our vision from this proactive work is for all industrial clusters to have fully engaged and explored the environmental capacity, impacts, and opportunities of deploying carbon capture and low and zero carbon technologies before they submit applications for environmental permits.

2.1. Role of the Environment Agency

The Environment Agency protects our air, land and water and enables a net zero nation that's resilient to climate change. We work with government, policy makers and developers to manage environmental risks at the earliest opportunity. We help industries prepare for necessary regulation. We also aim to build public trust in our regulation of the key environmental risks. As the primary environmental regulator in England, we are the principal regulator for industry in industrial clusters. We regulate water, energy, waste, and manufacturing sectors under the Environmental Permitting Regulations (England and Wales) 2016 (EPR), and carbon markets under the Greenhouse Gas Emissions Trading Scheme 2020. Crucially, and with reference to this pathfinder project, we are responsible for managing water resources in England. We safeguard water resources and ensure abstraction from surface and groundwaters do not damage the environment. By licencing water, we control the amount of abstraction to protect both water supplies and the environment under the Water Resources (Abstraction and Impounding) Regulations 2006, soon to be brought under EPR in 2023. We are the competent authority under the Control of Materials, Accidents and Hazards Regulations 2015 (COMAH) that covers the storage of hydrogen.

We play an influential role in levelling up, shaping places locally and nationally, advising on land use, conducting research, addressing flood risk and resilience, climate change adaptation, environmental protection, and nature restoration. We have a broad reach across industrial clusters from our site-specific interests to wider influence on regional development.

Our regulation of industrial emissions from industry in the Humber region includes around 12Mt of carbon dioxide per year. This contributes 37% of the combined carbon dioxide emissions produced by the 6 largest UK industrial clusters (Zero Carbon Humber 2021). The area contains a diverse range of existing and proposed industries such as traditional heavy industries, varied types of power generation, petrochemicals, and chemical manufacture. There are large scale plans for new low and zero carbon technologies such as carbon capture and hydrogen production. These aim to decarbonise existing industry and encourage development of new ones.

As a partner in the East Coast Cluster, the Humber Industrial Cluster contributes to the wider decarbonisation project that will eventually cover 50% of UK industrial emissions (Zero Carbon Humber 2021). The Humber is likely to be a cornerstone of the wider government aspirations detailed in “The 10 Point Plan”. The East Coast Cluster has been confirmed as one of the Track-1 clusters selected to be taken forward into Track-1 negotiations for development by the mid-2020s. The Government recently announced which local projects have met the eligibility criteria for Phase-2 sequencing. As such the Humber Industrial Cluster is an ideal location to conduct a pathfinder project to start to understand and plan for environmental capacity challenges.

The new industrial processes proposed for the cluster will need to be deployed rapidly and at scale. They will increase pressure on water resource and pose a risk to the local environment through the abstraction of water for use. They may also impact on water quality associated with the discharge of effluent and cooling water.

The pathfinder project is a pilot, starting to explore environmental capacity. It considers how we might construct a wider, more encompassing project in the future. We have chosen to focus on water use and water quality initially. Water use is known to be a key resource needed for both carbon capture and hydrogen production. The time limited nature of the project informed how we designed and set expectations for the work.

2.2. Project Objectives

The main objectives of this pathfinder project are to:

- Develop and trial an engagement approach with local industrial and place-making stakeholders to explore and identify the water quality, use, environmental needs, and challenges of deploying low and zero carbon technologies in one industrial cluster (Humber). This will inform local planning, mitigation action and regulatory decisions.
- Raise stakeholder awareness of: proposed carbon capture and hydrogen technologies used in the cluster; environmental capacity; and our regulatory role in managing the environmental risk. This will increase industry understanding and community confidence.
- Use the approach and learning from this project to shape our strategy for proactive engagement with stakeholders in follow-up industrial clusters.
- Strategically inform the extent to which environmental needs and capacity could limit wider technology deployment. It will enable us (Environment Agency), industry, and Government to anticipate, and prepare mitigation.
- Coordinate our contribution enabling UK Net Zero, focussing on industrial clusters.

3. Project Methodology

3.1. Overview

The project team comprised seven members of the Environment Agency. Members came with experience in climate change adaptation and mitigation, communications and engagement, and regulated industry. Five of the team worked on the literature review to draw the evidence together. Five worked on project management and communications and engagement exercise. This helped us to understand the anticipated needs and challenges of deploying low and zero carbon technologies directly from stakeholder groups. These two streams of evidence are brought together in this final report, conclusions, and recommendations.

3.2. Literature Review

The project team carried out a review of publicly available material to inform our understanding of the water use requirements of carbon capture and hydrogen production relevant and environmental capacity for low and zero carbon technologies planned for use across England. This includes information published by us, the Environment Agency, and organisations such as the United Kingdom Research Institute (UKRI), Carbon Capture and Storage Association (CCSA), United Kingdom Carbon Capture Storage Research Centre (UKCCSRC), Energy UK, Water Resource Regional Groups, Imperial College London, and the University of Sheffield, and where appropriate, also from European or UK government funded projects for decarbonisation and hydrogen supply.

The literature review provided the evidence base. This can be found in the technical review annex. It evaluates knowledge and assesses the collective evidence around environmental capacity and challenges.

We also launched a call for evidence from internal sources. This helped to establish an evidence base of current pressures. It advanced our knowledge on water resource in the Humber, and the likely impacts to water quality from low and zero carbon technologies. This process informed development of the engagement exercise. It focussed on potential limitations of a future environment. In response, local and national teams provided published reports on water requirements for low and zero carbon technologies; data on groundwater and surface water resource; and water quality data nationally and for the Humber region.

3.3. Stakeholder Engagement

Having established the current evidence base we recognised the need to engage with a wide range of stakeholders in the Humber region - to explore and understand the anticipated challenges of deploying low and zero carbon technologies.

We carried out a stakeholder analysis exercise to identify and prioritise those to engage. We identified over 118 stakeholders in our initial analysis that increased in number as we started our engagement. Prioritising this extensive stakeholder list was necessary due to tight project timescales, but our ambition is to extend this project to include other stakeholders identified in our analysis in a phase 2 project extension.

For this phase of the project, we focussed on engaging with three stakeholder groups directly associated with the Humber Industrial Cluster: internal (Environment Agency); industry and local place-makers (local authorities).

3.4. Engagement Methodology

Tight timescales meant there was limited time to engage which influenced our methods of engagement. We used questionnaires to capture the information required from our stakeholders. This allowed us to gather comparable information from many stakeholders quickly. With a view to understanding water needs, views and respective roles we developed three sets of targeted questionnaires, each directed to a specific stakeholder. Further information on the questions asked of each group can be found in the communications and engagement annex.

The key engagement activities were:

- Internal staff communications – to raise awareness of the project.
- Industry meetings - to introduce our project and listen to low and zero carbon proposals.
- Internal and external introductory email and/or telephone conversation - to introduce the project.
- Internal and external webinars with Q&A - to cement understanding and give opportunities to ask questions.
- Questionnaire (MS Forms) x 3 - to collect evidence from stakeholders.
- Meeting with one Local Authority (East Riding of Yorkshire Council) - to peer review engagement process and questions.

For this pathfinder project, we contacted thirty-two stakeholders from industry in the Humber region, twenty-four internal Environment Agency stakeholders associated with water, development, and industrial regulation and one local authority, East Riding of Yorkshire Council.

In carrying out this method of engagement we made some assumptions and identified the following barriers:

Assumptions: Stakeholders will want to fill out the questionnaire; Stakeholders hold the knowledge/information to complete it and would be willing to share it with us.

Barriers: The timescale to produce a questionnaire; The timescales given to stakeholders to digest what we're asking for and to complete the questionnaire; Whether stakeholder projects have progressed sufficiently to provide a response; Questionnaires often have a low response rate; Potential concerns about data protection and commercially sensitive information.

4. Evidence Evaluation

This section considers the current and future situation for water use, water quality and the requirements of the proposed low and zero carbon technologies in the Humber Industrial Cluster.

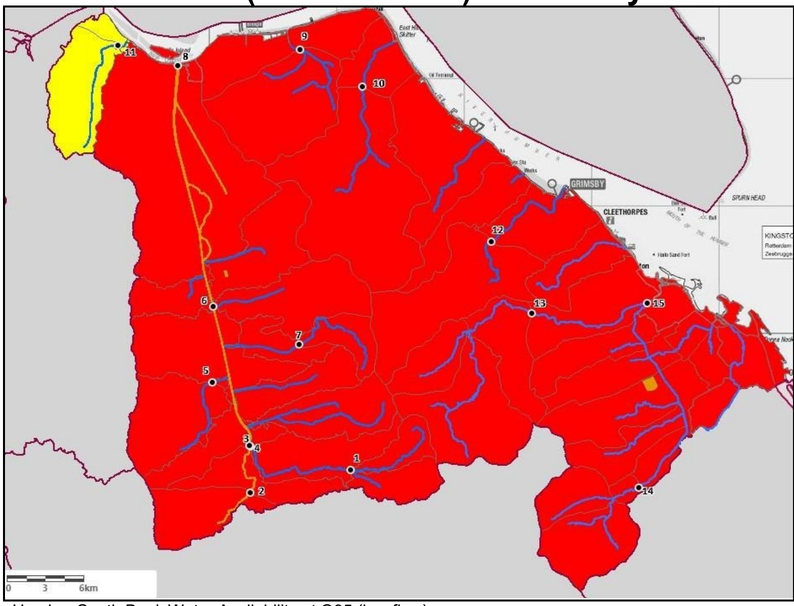
4.1. Water resources on the Humber

Our published Catchment Abstraction Management Strategies (CAMs) set out the framework for water availability for abstraction. These strategies tell us if there is water available or not. They are underpinned by extensive and detailed work to establish the extent of water resource. Our critical work to satisfy the Water Framework Directive (WFD) drives this indication of water availability and water quality.

We consider applications for abstractions from surface and groundwater resources. We consulted relevant area teams in relation to water supply for both Yorkshire and Lincolnshire and Northamptonshire. Our membership of both Water Resource East (WRE) and Water Resource North (WReN) and a consultee on the draft Water Resource Regional Plans.

The project examined several publicly available reports and publications that quantify and plan current and future water demand in the region. These are summarised below, with public water supply and planning provided by water companies. Long-term planning is now undertaken at a regional level by water resource regional groups. Direct abstractions by users from surface or groundwater supplies also play an important part in providing supply in certain areas or for certain types of use. This means that planning and supplying water is a complex issue.

Water resource (surface water) availability



Q95 (the flow of a river which is exceeded on average for 95% of the time i.e., low flow).

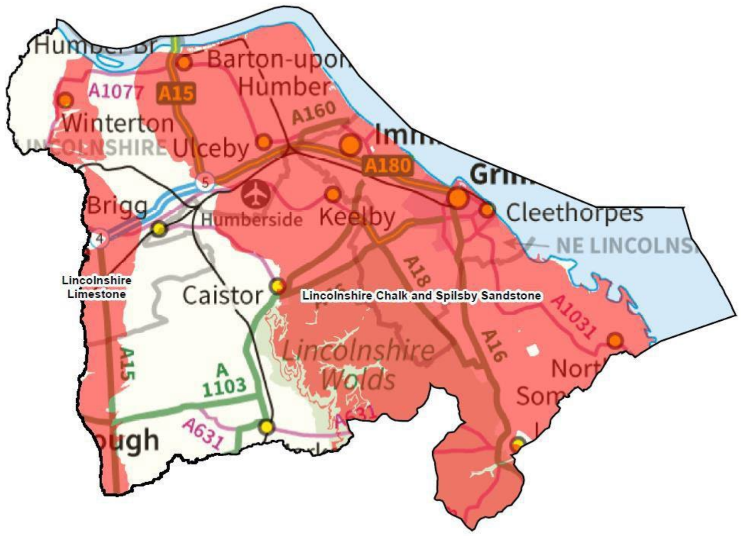
This scenario highlights water bodies where flows are below the indicative flow requirement to help support a healthy ecology in our rivers. We call this 'Good Ecological Status' (GES) or 'Good Ecological Potential' (GEP) where a water body is heavily modified for reasons other than water resources.

Note: We will not grant further licences.

Humber South Bank Water Availability at Q95 (low flow):

- Water available
- Restricted water available
- Water not available

Water resource (groundwater) availability



The red area:

Groundwater unit balance shows more water has been abstracted based on recent amounts than the amount available.

Note: We will not grant further consumptive licences.

'We know that water availability on the South Humber bank is constrained for surface water and groundwater currently, limiting or in some circumstances preventing new consumptive abstractions.' (Grimsby, Ancholme and Louth Abstraction Management Strategy, EA 2020).

4.2. Water companies

Public water supply around the Humber Industrial Cluster is provided by two water supply undertakers, Anglian Water and Yorkshire Water. The government asks water companies to provide a secure supply of water to their customers over a minimum 25-year period, at an affordable price without damaging the environment. Water companies in England and Wales must produce a water resources management plan (WRMP) every 5 years to show how they will achieve this. If a WRMP forecasts a deficit, then the water company must consider both supply-side options to increase the amount of water available and demand-side options which reduce the amount of water required.

- Anglian Water - The WRMP for 2019 plans from 2020 to 2045 and is supported by asset management plan (AMP) 7 that focusses on actions required in the period 2020 to 2025. The plan (running up to 2045) recognises that the companies supply-demand balance is under significant pressure from population growth and climate change, and the need to increase resilience to severe drought. It therefore seeks to improve the resilience of public water supplies by adapting to climate change, enhance the environment by reducing abstraction in sensitive areas, and fully consider every potential water resource option. The aim of the evidence review was to inform our understanding of any recognition of or planning for water demand associated with carbon capture and hydrogen production.
- Yorkshire Water – The stated aim of WRMP19 is to support a reliable and sustainable supply of good quality, clean water. The plan describes how Yorkshire Water will ensure they can continue to have sufficient water to supply their customers, in the face of future challenges such as climate change, population growth and environmental pressures. The WRMP sets out Yorkshire Water plans to maintain a balance between supply and demand for the minimum statutory 25-year period from 2020 to 2045.

WRMP24s are currently being developed and draft plans will be available in Autumn 2022. We are seeing that the level of resilience needed for these new plans is different to previous resulting in a change in the availability of water, usually meaning less is available than stated in the WRMP19. It must be noted that the current plans do not include new work on water requirements as developed by Energy UK – forecast requirements to 2050.

4.3. Water Resource Regional Plans (WRRP)

We published “Meeting our Future Water Needs: A National Framework for Water Resources” in 2020. The National Framework explores the long-term needs of all sectors that depend on a secure supply of water. This includes public water supplies provided by water companies to customers’ homes and businesses, direct abstraction for agriculture, electricity generation and industry, and the water needs of the environment.

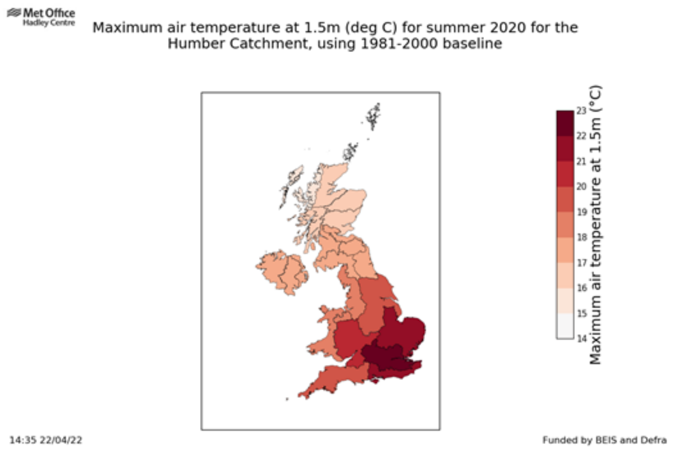
In summary the plan suggests an overall regional surplus for the north. It includes a forecast of increasing demand due to population increase, drought preparation and climate change. With an increase in demand from the power generation sector but no specific mention of likely demand from low and zero carbon technologies. The plan also suggests likely significant water demand pressure for the east. It includes a forecast of increasing demand due to population increase, drought preparation, environmental improvements, and climate change.

The framework creates a consistent approach to water resource planning at the regional level. There are specific plans for each region. There are five regional groups preparing regional plans to plan for the provision of water supply for the period 2025-2050. These focus on a collaborative approach to water resource planning involving regulators, other water users, and water companies. The five regional groups include the relevant water companies for the individual regions. WRRP’s are intended to inform the development of the water companies WRMP’s, with an increasing emphasis on the need to consider resource at a regional level. Of relevance to this project are the regional groups for the East of the country (Water Resources East) and the North (Water Resources North).

- Water Resource East (WRE) - We accessed the draft WRRP, (The emerging water resources regional plan for Eastern England). The plan acknowledges carbon capture and hydrogen production is likely to drive additional water use requirements. An additional need of 444 Ml/day for other users (industry, agriculture, and power generation) being forecast for the period up to 2050 (Meeting our Future Water Needs: A National Framework for Water Resources). The plan references that with the drive to net zero carbon emissions, the energy sector is likely to need up to 181 Ml/day more freshwater to facilitate the potential switch to greener technologies such as carbon capture, and hydrogen production through the electrolysis of water. In the WRE region, the plan references an expectation that the South Humber Bank and the Lower Trent Valley will be a focus for this new demand.
- Water Resource east and North (WReN) - We accessed the draft WRRP, (Emerging plan for consultation). The aim of the literature review was to inform our understanding of any planning for water use requirements associated with carbon capture and hydrogen production. The plan references the likely need for additional water use requirements associated with technologies related to decarbonisation. An additional need of 119 Ml/day for industry including power generation) being forecast for the period up to 2050 (Meeting our Future Water Needs: A National Framework for Water Resources). Non-public water supply predicted demand increases are further broken down into sub-sectors but there is no separate section for carbon capture or hydrogen production. Only a relatively modest increase is predicted for the power sector (rising from 60.06 to 73.77Ml/day) by 2050. An even smaller rise is predicted for the chemical sector (2.92 to 3.57Ml/day) by 2050.

4.4. Likely impact of climate change on water resources and water quality in the Humber

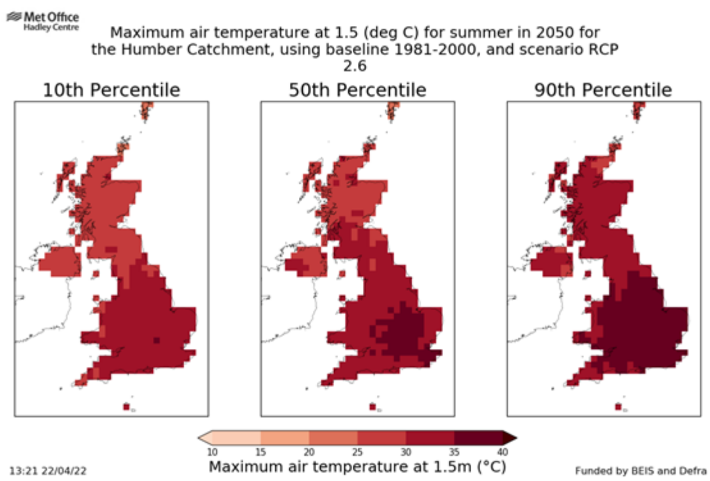
According to the latest United Kingdom Climate Change Projections (UKCP) (UKCP18, Met Office, 2018) the UK can expect warmer wetter winters and hotter drier summers along with an increase in the frequency and intensity of weather extremes. By the end of the 21st Century all areas of the UK are expected to be warmer, more so in summer than winter.



Global land temperatures have already risen by 1.1°C, and further increase is inevitable due to the carbon emissions of the past. Temperatures will soon be teetering on the edge of +1.5° C, which is the most optimistic international goal, with +2° C in sight. Climate data indicates that average temperatures in the UK have risen by 0.3° C in the decade between 2008-2018 compared to the average temperature between 1981-2010, showing the UK temperature trend is increasing.

Modelling has shown that by 2050, in the Humber region, the annual average daily air temperature will increase between 2-5°C with a corresponding increase in river temperature. This is based on UKCPs medium-high emissions scenarios (Yorkshire and Humber Regional Adaptation Study, 2019). According to the latest State of the UK Climate, 2020 was the third warmest, fifth wettest and eighth sunniest on record. Around 1.15 Ml/day is required to make supplies more resilient to drought. (Meeting our water needs: a framework for water resources, EA, 2020).

Rainfall patterns are not equal across the UK and vary by season and region. This variation will continue in the future. Overall winters will become wetter, and summers will become drier, presenting greater challenges on how water is managed. Average rainfall for the Humber in winter could increase by 29%. Summers will be drier with potentially 34% less rain than today (Adaptation to climate change risk assessment worksheets for river basin districts, EA, 2019). Temperature is likely to contribute to a reduction in the length of the groundwater recharge season, reducing by as much as 30% for chalk catchments in the Humber region (Living with Environmental Change – Water Climate Change Impacts Report Card, EA 2016).



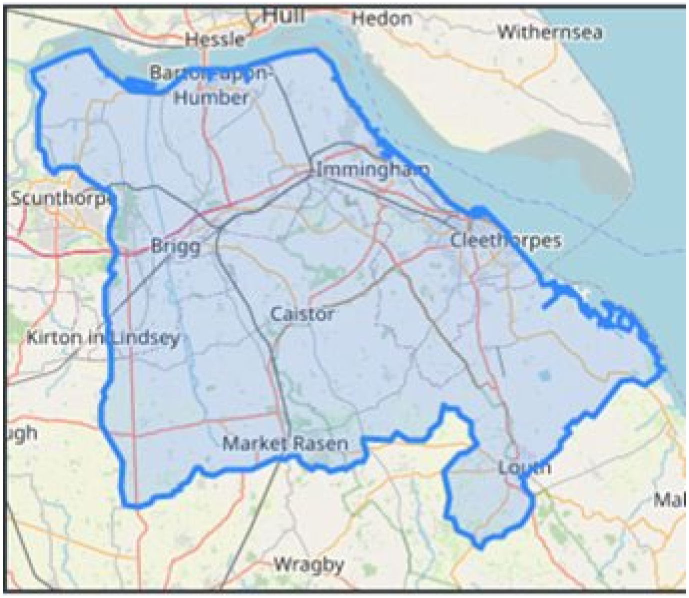
400Ml/day of water between 2025 and 2050 is needed to address the impact of climate change on water use in the UK, a figure that doesn't include the impact on water supply from population growth (Meeting our water needs: a framework for water resources, EA, 2020). To counteract this need for more water four climate change scenarios have been modelled. These tell us that a reduction in abstraction between 1,200Ml/day and 2,200Ml/day will be needed to support public water supply and the environment by 2050.

In the north of the Humber region, water supply needs due to climate change is expected to increase by 132Ml/day between 2025-2050. In the east the figure is 76Ml/day.

It is important to mention the climate change impacts on water quality when discussing water resources. Variations in the seasonal intensity of heat and rainfall will affect water needed for environmental protection, exacerbated by temperature and low river flows. Changes in river flow regimes because of climate change will consequently result in less volume of water for dilution of industrial effluents. This will cause higher concentrations of pollutants downstream of discharges, and greater potential impacts from cooling water.

Other climate change impacts on water quality include summer rainfall intensity that leads to greater levels of suspended solids in rivers that lower dissolved oxygen levels. Ambient river temperature increases also affects dissolved oxygen levels and presence of toxic algal blooms. Storm water from intensive rainfall increases the incidences of combined sewer overflow discharges into rivers (Potential impacts of climate change on river water quality, EA, 2008).

Climate change could also affect rivers which are already impacted. For example, where multiple water bodies north and south of the Humber are given the ecological status of 'moderate - change from natural conditions because of human activity and improvement is needed', climate change increases the challenge to mitigate potential impacts from low and zero carbon technologies. (River Basin Management Plan – Humber, EA, 2021).



Moderate surface water ecological status - South Humber Bank, Louth, Grimsby, Ancholme catchments

Moreover, climate change may cause saline intrusion of chalk aquifers due to rising sea levels. This would result in an increased hydrostatic pressure, as well as an imbalance in rainfall recharge to the aquifer and the amount of groundwater abstraction taking place. Saline intrusion occurred in the Yorkshire Chalk aquifer due to exploitation during the 19th and 20th centuries. It has since stabilised due to a decline in industrial abstraction and an enforced reduction in private groundwater abstraction. (The Geological Society The Geological Society (geolsoc.org.uk))

4.5. Water requirements of low and zero carbon technologies

The project examined several publicly available reports and publications. These detail water requirements for specific low and zero carbon technologies and aim to understand what the water requirements might be for these technologies, and the energy sector, through to 2050. These are summarised below.

Hydrogen Production

The three main technologies being considered in the Humber Industrial Cluster for Hydrogen production are:

- Electrolysis Proton Exchange Membrane or Polymer Electrolyte Membrane (PEM)
- Steam methane reforming

- Gasification (of various feedstocks)

The first of these, the production of hydrogen via electrolysis, is often referred to as 'Green hydrogen' due to there being no emissions of greenhouse gases from its production. The second and third methods are often referred to as 'Blue hydrogen', but only where the carbon dioxide has been captured. The production of blue hydrogen often involves steam reforming of methane or other volatile organic compounds (VOCs) which result in the production of carbon dioxide. As a result, blue hydrogen technology requires additional abatement to remove the carbon dioxide produced.

- **Electrolysis PEM**

  Hydrogen electrolysis with PEM offers rapid dispatchability and turn down to follow the energy output from renewables and is therefore ideal for pairing with wind farms for low carbon hydrogen production or the provision of rapid response to the grid.

  Water consumption is typically:

  Table 1

		Litres Water/Kg H2		
Source of Water	**Use**	**Total**	**Consumptive**	**Returned**
Demineralised*	H2 production	10.5	10.5	0
Potable*	H2 production	20	10	10
Saline (seawater)**	H2 production	30	13	17
		M3/hr		
Saline (seawater)**	Cooling	60	20	40

* Hydrogen supply chain evidence base. Prepared by Element Energy Ltd for the Department for Business, Energy & Industrial Strategy November 2018
** Response from Uniper Hydrogen UK Limited to the EA questionnaire

The above figure of 20 litres potable water compares with that proposed by the Gigastack Renewable Hydrogen Project, led by a consortium of ITM Power, Ørsted, Phillips 66 Limited and Element Energy (Phase 2: Pioneering UK Renewable Hydrogen Public Report. Department for Business, Energy & Industrial Strategy). It is noted though that the Gigastack project is intending on utilising wastewater from the Humber refinery although no information was obtained to determine how much is consumed and how much is returned as a wastewater.

Table 2

Technology	Units	MEP	GEP
System Size	MWe	2.0	5.0
System Efficiency	%(HHV)	68	73
Hydrogen Production Capacity	kgH2/hr/system	34.5	92.6
Wastewater	Litres/kg H2	20	17

MEP = Megastack Electrolyser Platform
GEP = Gigastack Electrolyser Platform

- **Steam methane reforming**

Steam Methane Reforming (SMR) is a chemical process used in the gas manufacturing industry to produce hydrogen on a large scale. This process contains two chemical reactions which ultimately convert water and methane (usually in the form of natural gas) into pure hydrogen and carbon dioxide.

Table 3

Source of Water*	Litres Water/Kg H2
Raw water H2 production	4.7
Raw water for cooling	5.5
OR Saline water for cooling	1,170

Note: The difference in cooling/sea water usage is the difference between using a cooling tower and the small temperature increase allowed for discharged sea water.

* Hydrogen supply chain evidence base. Prepared by Element Energy Ltd for the Department for Business, Energy & Industrial Strategy November 2018

In response to our questionnaire, Uniper Hydrogen UK Limited provided the following information:

Table 4

		Litres Water/Kg H2		
Source of Water	Use	Total	Consumptive	Returned
Demineralised	H2 production	8	8	0
Potable	H2 production	11	Not reported	Not reported
Saline (seawater)	H2 production	25	11	14
Saline (seawater)	Cooling	20	8	12

- **Gasification**

Gasification technology allows for the transformation and upgrade of a solid fuel into a mixture known as syngas. This syngas may be separated and purified to produce high purity carbon dioxide and hydrogen streams. Ca 11 litres water/Kg H2 produced may be required. (Hydrogen supply chain evidence base. Prepared by Element Energy Ltd for the Department for Business, Energy & Industrial Strategy November 2018)

Of the technologies listed, most of the hydrogen production proposed for the Humber Industrial Cluster will be via a mix of electrolysis and steam methane reforming.

Based on the information provided in our stakeholder questionnaire we gained some understanding of the additional water requirements for low and zero carbon technologies to be deployed.

H2H Saltend Equinor New Energy Limited - Blue Hydrogen process:

Two projects are being proposed with the estimated water requirement quoted as being 450m^3/hr however, this is expected to reduce as the design is finalised. The response to our questionnaire was for the first project: 600MW H2 production at PX Saltend Chemical Park which is expected to require ca 3.8Mm^3/year of water which will be provided by Yorkshire Water via the PX Saltend Chemical Park site.

The second project: 1200MW H2 production for a new hydrogen power plant at Keadby is expected to require ca 7.6Mm^3/year of water. It must be noted that the response provided to our questionnaire was in relation to the Project I development. The calculation for Project II is based on a ‘doubling’ up of production and therefore water use. It was not possible to determine from the response how much water would be consumed by the process and how much would be returned as a wastewater.

Project I is an additional water requirement. It is not known how much additional water will be required for Project II.

Uniper Hydrogen UK Limited:

Green Hydrogen based on 100MWe hydrogen production.

Because the final design and choice of technology has yet to be confirmed, several scenarios for water use have been presented. Uniper Hydrogen UK Limited has access to an existing abstraction licence to take estuarine water from the Humber estuary and they have connections to Anglian Water potable and non-potable water supplies. Under the current arrangements, Uniper Hydrogen UK Limited would not require any additional water for these proposals.

Table 5

Source of Water	Annual Water Requirement **Mm^3/year** All consumptive figures
Demineralised – H2 production	0.14
Non-potable – H2 production	0.14
Saline – H2 production	0.18
Cooling	0.18

Worst case water requirement is ca 0.36Mm^3/year.

<u>Uniper Hydrogen UK Limited</u>:

Blue Hydrogen based on 720MW hydrogen production.

Table 6

Source of Water	Annual Water Requirement Mm^3/year
Demineralised – H2 production	1.53[a]
Non-potable – H2 production	2.10
Saline – H2 production	2.10[a]
Cooling	1.53[a]

a: Consumptive amount

Worst case water requirement is ca 3.63Mm^3/year which includes cooling water requirements and all of which is consumptive.

<u>Gigastack:</u> Whilst Gigastack did not provide a response to our questionnaire, with reference to Table 2 above and their website we can deduce that their proposal will require 0.28Mm^3/year (Phase 2: Pioneering UK Renewable Hydrogen Public Report. Department for Business, Energy & Industrial Strategy): The calculation above is based on the intention to install 100MWe capacity = 20 X 5MWe GEP units. Each unit requires 17 litres water/kg H2 produced, and each unit can produce 92.6Kg/hr H2.

The Gigastack concept explored additional supply, recycling effluent wastewater from the Humber Refinery and desalination, and have opted to use effluent wastewater from the Humber Refinery based on a cost benefit analysis. This ensures that there is no increase to the industrial water demand in the region and provides an innovative way of recycling refinery effluent water.

Despite only gaining a limited understanding of the water requirements for proposed green and blue hydrogen technologies to be deployed in the Humber Industrial Cluster, the information provided confirms our understanding that significant amounts of water will be required both to produce hydrogen and capturing the carbon dioxide.

Carbon Capture

Information on the amount of water required for carbon capture is limited. Carbon capture is being proposed for the Uniper Hydrogen UK Limited blue hydrogen project and, assuming carbon dioxide is used as a cushion gas, by Centrica Storage Ltd also. Estimates of water requirements for the whole process have been provided as opposed to a breakdown for specific activities.

VPI Immingham are proposing to retrofit amine-based carbon capture technology to their existing combined cycle gas turbine (CCGT) units and auxiliary boilers. Whilst VPI Immingham did respond to our questionnaire they were unable to provide an estimate on how much water would be required for the process.

A literature search obtained the following information (The water footprint of carbon capture and storage 2 technologies. Department of Environmental Science, Policy, and Management, University of California, Berkeley): A natural gas CCGT retrofitted with post-combustion carbon capture has an average water footprint of 2.59 [2.37 to 3.16] m^3 per tonne of carbon dioxide.

VPI Immingham have informed the EA that their initial intention is to capture 3.3Mt/year of carbon dioxide. Based on the above average water requirements that equates to a total water requirement of 8.6 Mm^3/year (both potable and non-potable).

Anglian Water currently supplies raw water for the existing plant and will supply additional water for the low carbon project. However it is not known how much additional water will be required for this project.

We are aware that carbon capture is being proposed by at least two other industries within the Humber Industrial Cluster, Drax Group Plc (Drax Power Station) and Keadby Generation Limited (Keadby 3 Carbon Capture Power Station) however, we did not receive a response to our questionnaire from these operators.

4.6. Projection of water requirements for the Humber Industrial Cluster through to 2050

As outlined above, hydrogen production and carbon capture can use potable, non-potable, saline, and wastewaters for cooling, as well as a raw material in the generation of electricity; production of hydrogen; and capture of carbon dioxide.

At the geographical scale of ‘East of England’, which incorporates the South Humber Bank, the long-term energy transformation towards net zero greenhouse gas emissions in 2050 may result in considerably higher freshwater demands for power production than in recent history (Projections of Water Use in Electricity and Hydrogen Production to 2050, under the 2020 Future Energy and CCC Scenarios including BEIS 2020 lowest system cost analysis – with a focus on the East of England).

Table 7

Period	Annual Mm^3/annum	Ml/day
Current	15 – 25	260 – 330
2025	<6	<100
2050	160[a]	500[b]
	200[c]	600[c]

a: Under significant deployment of hydrogen (under the FES20: ‘System Transformation’)
b: Under a stress event, including hydrogen production
c: Under the most demanding deployment rule (‘tighter coastal/estuarine regulation’)

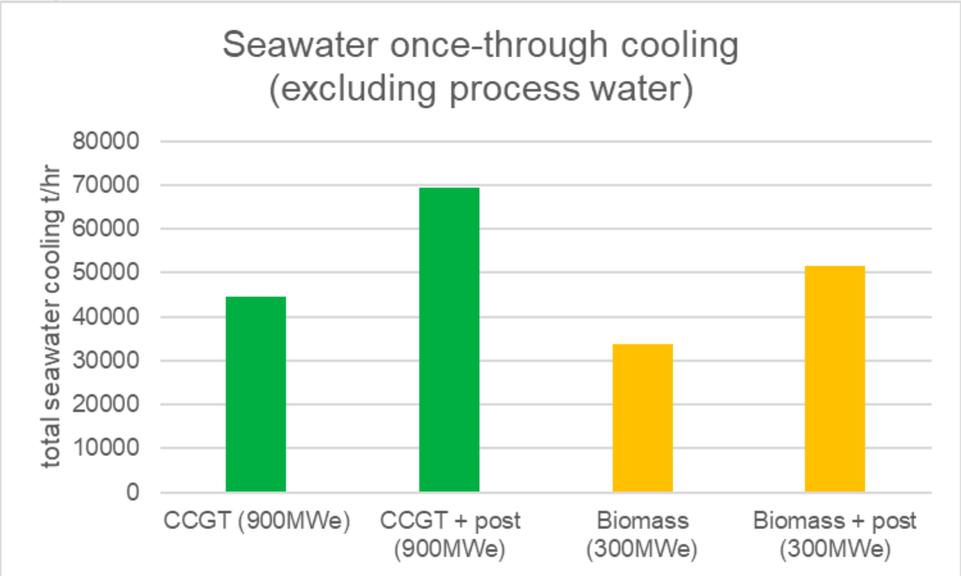
For electricity producers, most of the reported freshwater consumption is associated with cooling purposes (at riverine or tidal freshwater locations). However, all power plants need access to High Quality Water (HQW), or demineralised water (for non-cooling uses). This is often supplied by public water (potable) supply. The amount of HQW annually consumed by electricity producers in 2050 is modelled to be up to 5Mm^3/annum for the East of England. Much greater HQW annual consumptions are estimated for hydrogen producers at up to 60Mm^3/annum.

Alternative methods can be used to reduce reliance on the requirement for cooling water however water is normally preferred by industry and is considered Best Available Technique (BAT).

- Once through (direct) cooling is the least complex, most thermally efficient, and often cheapest option. It uses by far the greatest gross volume of water but with very little consumed in the process (less than 1%).
- Tower and hybrid (indirect) cooling facilitates the evaporation of water to remove waste heat. Less water is required compared to a once through system, but indirect cooling has the highest consumptive demand. Almost 50% of the abstracted water required for cooling on a CCGT is lost to the atmosphere. These systems are typically 0.5% - 2% less efficient than direct cooling.
- Dry/Air cooling requires only small amounts of water in a closed, re-circulating water circuit. The heat generated is transferred to the atmosphere as hot air by motor driven fans. This system is 2% - 3% less efficient than direct cooling. (Water Use and Electricity Generation – EA December 2013)

The graphs below summarise the cooling requirements for the two main types of cooling likely to be used in the UK: seawater once-through cooling for coastal power stations and hybrid cooling towers for inland power stations. The estimated additional cooling water flow rates in tonnes/hour, assuming post amine carbon capture technology is employed, vary from 52% to 55% depending on the fuels used and the power station design. (Water Demand for Carbon Capture and Storage (CCS) Environment Agency November 2012).

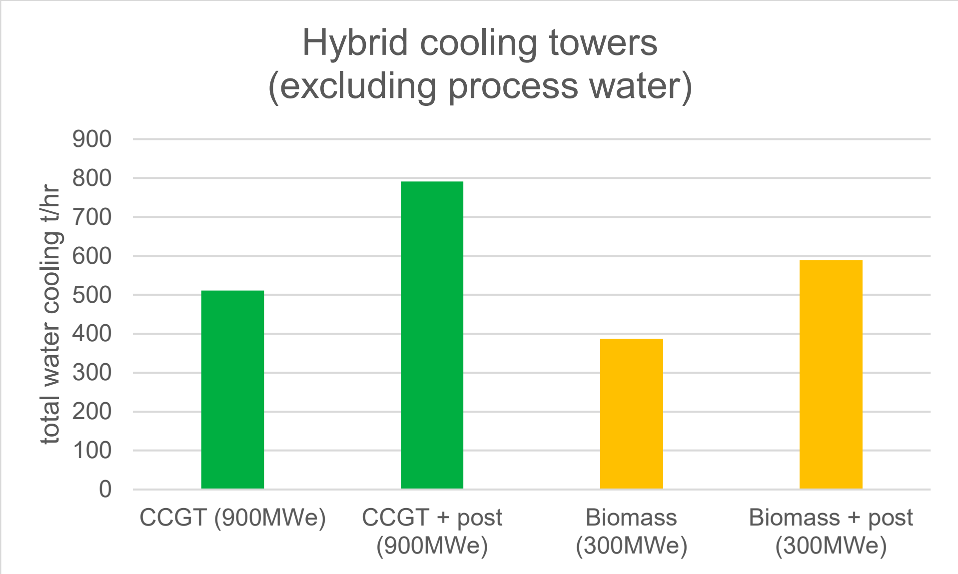
Graph 1



By way of example, based on the information provided in those above, a CCGT plant operating in mid-merit (one which runs a maximum of 4,000hrs/year generation) would require:

- Once Through : without carbon capture: 179Mm^3/year
- Once Through : with carbon capture: 277Mm^3/year (an extra 98Mm^3/year)
- Hybrid : without carbon capture: 2.0Mm^3/year
- Hybrid : with carbon capture: 3.2Mm^3/year (an extra 1.2Mm^3/year)

Graph 2



5. Stakeholder engagement and review of stakeholder technical responses

A significant proportion of this pathfinder project involved planning and carrying out engagement with stakeholders. We will ensure that any future engagement around environmental capacity will consider any lessons learned from this pathfinder. Therefore, as part of this project, we have evaluated the process of our engagement and the outcomes.

5.1. Were the engagement objectives met?

Our objective was to engage with a range of stakeholders to: raise awareness of; and to identify and understand the anticipated needs and challenges of deploying low and zero carbon technologies. We reached all our target stakeholders from the Environment Agency (internal); industry and one local authority (East Riding of Yorkshire).

We sent out thirty-six invitations to our webinars, of which we had thirty-two attendees. The webinars worked well as an introduction to the project – each webinar was well attended, and the information and question and answer (Q&A) sessions were well-received by participants. Participants engaged in the webinars - they listened to us, asked questions and made comments.

We sent out fifty questionnaires and received thirteen responses in total (eight from internal stakeholders and five from industry stakeholders). We met with one exemplar local authority (East Riding of Yorkshire Council) and received input and feedback.

The 26% return on the questionnaires was significantly less than we hoped, especially given the good attendance at each webinar, but we acknowledged the limitations of using a questionnaire as a potential barrier from the start. We received input from internal staff outside of the formal questionnaire which has been included in the report.

The method of using a questionnaire was appropriate given the time constraints and it allowed us to understand and compile individuals' specific concerns. Given a longer timeframe workshop or focus group engagement could have yielded more qualitative information; it would give the opportunity to explore technical issues in more depth, would give immediate results and the interaction between participants could lead to interesting themes.

5.2. What impact did it have?

We achieved our outcomes – we received information from representatives from our target stakeholder groups albeit less than we'd anticipated. It also raised awareness of environmental capacity (for low and zero carbon technologies) at an early stage to many stakeholders.

This phase of the project has started to build good working relationships with fellow stakeholders involved in decarbonising industry in the Humber region. This engagement should smooth the way for engaging in future phases of this work.

This pathfinder project has helped us to clarify which methods of engagement work well. We will build on this work to refine an engagement and comms strategy for any future work in the Humber Industrial Cluster and other industrial clusters.

5.3. Water resources

Additional water use will be required for both hydrogen production and carbon capture. Advanced indications are that a significant volume of clean water is needed. This is also indicated by the Joint Environmental Programme (JEP) (Projections of Water Use in Electricity and Hydrogen Production to 2050, under the 2020 Future Energy and CCC Scenarios including BEIS 2020 lowest system cost analysis – with a focus on the East of England) research on potential consumption needs under various deployment scenarios, but circumstances are changing rapidly.

A key element of this pathfinder project is to understand water requirements for the various low and zero carbon technologies being considered in the Humber Industrial Cluster. The use of water is becoming a significant concern in the deployment of these technologies south of the Humber. Water demand for carbon capture, blue and green hydrogen production will vary but the long-term energy transformation towards net zero greenhouse gas emissions in 2050 may result in considerably higher freshwater demands for power generation than in recent history.

Of the industry stakeholders we engaged with, and provided a response our questionnaire, we obtained five responses. Most of the respondents stated they have access to enough water for existing and future operations, excluding low and zero carbon technologies. However, there is more uncertainty when considering the additional water requirements for low and zero carbon technologies. One respondent stated they do not have access to sufficient cooling water whilst another has not yet determined what their specific needs will be.

Whilst some of the industry respondents did provide details on what they thought their additional water requirements might be, it was noted that a number are still at the pre-Front End Engineering Design (pre-FEED) stage and have not yet decided on their preferred technology or design. Therefore, the details provided may change as designs are finalised.

Of note, is that all five responders stated they are either fully reliant on water being provided by a utility provider or are at least partly reliant. Those partly reliant on a utility provider are either considering obtaining additional water via new abstraction licences and / or re-use of industrial wastewaters either from their own processes or from neighbouring industrial sites.

No concern was noted by our place-maker stakeholder as the remit of the local planning authority relates to site drainage and flood risk when assessing the management of water for a proposed development.

The main challenges for water resources are known current limitation for water use in the region, future challenges attributable to climate change, and conflicting needs. Competition will likely increase between industry and other users for the same resource. We must meet our statutory duty to protect, preserve and improve the environment. Therefore, we need to be prepared to address conversations on prioritising water for low and zero carbon technologies.

There are significant existing challenges around water use in the Humber region, particularly south of the estuary, so innovative water solutions will need to be explored. In Lincolnshire and Northamptonshire, the current trajectory and position is that no new consumptive water is available on the South Humber Bank. Non-consumptive licenses will be considered on a case-by-case basis and will be time limited. There is a potential opportunity to explore groundwater abstraction at extremely high groundwater levels, but again this will be considered on a case-by-case basis.

Significant growth in water abstractions in East Yorkshire is expected, and more water will be needed to meet environmental objectives, i.e., fish passage, flows to meet environmental objectives for chalk streams. This pressure also applies to Yorkshire Water who may be required to reduce their abstractions in these locations in the future to meet environmental objectives.

In Yorkshire, we would constrain most licences using a Hands-Off Flow as measured in a river gauge, this would also apply to chalk groundwater use. Water from the deeper Sherwood Sandstone Aquifer is controlled differently and any new water may need to be traded from another licence holder or unused source.

We can offer applicants advice and guidance at the permit pre-application stage via our basic or enhanced pre-application service. We undertake an initial assessment to ensure that information is correct and give guidance on water usability. Typically, our pre-application advice is dictated by the level of information included in the pre-application. The more detailed information that we are given (on the water needed, likely discharge type, and location) the more advice can be provided. The applicant should consider multiple sources including building storage on site for the water needed, rather than solely relying on taking it from the environment. Water resource licenses are issued on a case-by-case basis and the onus is on the applicant to demonstrate no negative impact.

Technology readiness levels (TRLs) are a method for estimating the maturity of technologies. The use of TRLs enables consistent, uniform discussions of technical maturity across different types of technology. A technology's TRL is determined during a Technology Readiness Assessment (TRA) that examines program concepts, technology requirements, and demonstrated technology capabilities. TRLs are based on a scale from 1 to 9 with 9 being the most mature technology.

Most of the individual technologies being proposed by those who responded to our questionnaire are at the most mature level and are already established in several applications around the world. What is different about the projects within the cluster, from a UK perspective, is the way the individual technologies are combined, their scale and the proposed rate of deployment.

From the responses received, operators are giving consideration to the potential impact of a changing climate on the long-term availability of their preferred water supply. Three of the responders consider there to be no issues. Of these, one does not anticipate any issues as they are proposing to use direct air cooling and hybrid cooling. Another is proposing to use seawater for cooling and again, do not anticipate any issues. A separate responder however, states that the project will need to be certain that sufficient water is available for the operational lifetime of the blue and green hydrogen production facilities before a financial investment decision is made to proceed.

East Riding of Yorkshire Council recognised that responsibility for water supply falls to water companies but under the planning system there could be an opportunity to address sustainable water supply and water use in a planning application. This opportunity is discussed further later in this section.

Water efficiency is a key aspect of BAT for hydrogen production and carbon capture and storage plants. Water will be used as a raw material in hydrogen production, heat transfer, and for cooling.

The applicant will need to consider ways to minimise water use, segregate and secure the water needed for the process without relying on natural water sources. Guidance is available outlining the options. These could include water recycling and re-use, considering alternative sources, harvesting grey water, desalination, and potential use of saline water if water quality is not important. This also includes choosing cooling methods to comply with relevant guidance.

There may be an opportunity to better integrate wastewater treatment across several sites. Because we have 'clusters' of sites in proximity to one another, a company's water requirements may lie in a resource-sharing approach, combining with neighbouring companies and tapping into expert help and water facilities designed for industrial use. This approach is already being used at PX Saltend Chemical Park on the north side of the Humber.

The pre-FEED stage is the point at which water requirements and water efficiency methods are taken into consideration. All industry responders have considered alternative solutions to their water requirements. Of these, two stated that water use, or the sustainable supply of water, has influenced the technology chosen. One respondent is still considering the use of either potable, non-potable or saline water which will influence the choice of 'blue' or 'green' hydrogen technology they employ. A second is having to consider the use of air or hybrid cooling as there is insufficient water available for their chosen carbon capture technology. Two respondents have considered use of on-site and off-site effluent water either reused directly or after on-site treatment.

The location of the Humber Industrial Cluster lends itself to use of saline water for once through cooling. Saline water is currently used by Triton Energy at the Saltend Chemical Park on the north side of the Humber for cooling and is being proposed by Centrica Storage Ltd – compression of Hydrogen for storage in the Rough Reservoir. However, recovery of 'waste' heat will need to be assessed as part of any permit application e.g., organic rankin cycle (ORC) engines can be used to recover low grade heat for the generation of electricity thereby reducing the amount of water required for cooling.

Our place-maker stakeholder, East Riding of Yorkshire council, believes it is possible to help mitigate environmental challenges facing low carbon technology such as water use through the planning system via specific planning applications. Water supply decisions may influence the infrastructure required and site layout of a proposal. It is not uncommon in the planning system for requirements to be placed on applicants to specify the management of water on site, Sustainable Urban Drainage Systems (SUDs) is one such example. The sustainable supply of water could be a requirement of planning applications prompting early dialogue between applicants and regulators.

Transfer of water from a region where consumptive stress is less than in North Lincolnshire for example, may help alleviate that stress. WReN have considered the option for a bi-directional link between Yorkshire Water and Anglian Water but that requires further investigation for its feasibility to be confirmed. WRE regional assessment suggests that this option may merit testing at a later date. As such, no water exports from the WReN area have been selected by other regions in their plans, however, these possibilities continue to be explored. (WReN Water Resources North. Emerging Plan for Consultation January 2022).

5.4. Water Quality

Advance implications for both hydrogen production and carbon capture are that large amounts of clean water are needed. But water quality needs and impacts can only be confirmed with full understanding of how the intended technology operates and any related discharges that may affect water quality. This emphasises the need for early dialogue and may inform the viability of low and zero carbon projects.

Our ‘No Deterioration’ policy aims to prevent increases in concentration and load of pollutants within a catchment. It also seeks to prevent deterioration in classification and status. There are existing challenges to water quality in the Humber. These include regular low dissolved oxygen levels during the summer months in the lower reaches of the River Ouse and in the upper reaches of the Humber estuary, and failed Water Framework Directive standards for angiosperms, invertebrates, dissolved inorganic nitrogen (DIN) and a range of chemicals. There is also a risk of abstraction-driven saline intrusion where deeper groundwater is pulled in from the coast as a result of climate change increasing sea level, and impacts on water quality of the wider groundwater body.

The Humber is heavily protected for ecology and water quality including under the WFD and Habitats & Birds Directives. The Humber Estuary is designated as a Special Area of Conservation (SAC) and a Special Protection Area (SPA) under the Habitats Regulations and Ramsar Convention.

Low and zero carbon technologies are less understood than tried and tested technology such as combined cycle gas turbines (CCGTs) for electricity generation. For the less understood, the environmental permitting decisions are less developed. Within the Humber there are existing water quality concerns so permitting additional discharges could be problematic. The River Humber’s conservation designations may limit what is permissible in the immediate vicinity; sewage works, and sewer capacity may also limit the extent of what is permissible without improvements put in place.

Initial scoping by the Environment Agency Chief Scientist’s Group suggests that potential water quality impacts of the processes intended in the Humber Industrial Cluster include thermal pollution, pollution from amines in wastewater, and some storage integrity issues for above-ground leakage and contamination.

Clearly there will be an increase in the amount of wastewater and potentially an increase in the number of discharges of wastewater by introducing low and zero carbon technologies. None of the responders were able to state by how much wastewater volumes would increase nor how many additional discharge points there may be.

Many of the industrial units within the Humber Industrial Cluster share several utilities, wastewater treatment and discharge points being one. Two of the responders confirmed additional wastewaters would be treated by existing treatment plants prior to an ‘indirect’ discharge although one of these, the Saltend Chemical Park, can discharge to the public foul sewer system (indirect) or to the Humber Estuary (direct) depending on the quality of the wastewater. An additional two were unable to provide an answer on whether their discharges would be ‘indirect’ or ‘direct’.

Three of the responders did confirm that their wastewaters are likely to require some form of treatment prior to discharge whilst one was unable to confirm. Of these, two confirmed that their discharges may have an additional impact on the receiving environment, one acknowledged the potential to discharge heat and chemicals to the environment needs further consideration during their concept development phase.

When carrying out an appropriate risk assessment for assessing emissions to the environment, operators should be advised to conduct an in-combination assessment of their releases i.e., that localised releases to that same environmental body are taken into consideration. Since a number of these industrial sites are discharging their wastewaters to a ‘common treatment plant’, a careful assessment of the cumulative impacts on that treatment facility is required to ensure that it remains fit for purpose and that, if the final discharge is direct to a water course, it does not have an adverse impact on it.

One key area of concern will be discharge temperatures. It is expected that, assuming sufficient water is available, water will be used for several cooling processes resulting in the potential for an increase in thermal discharges.

Any planning advice on water quality would be focussed on the designations and legislation that protect the Humber estuary as well as local chalk streams and their downstream reaches, mainly the Habitats Directive and the Water Framework Directive (WFD). Any proposed schemes in this area must consider the requirements of the legislation and be designed to not adversely impact the estuary. Permit conditions would be applied to limit any activity likely to adversely impact water quality as per the requirements of the WFD and need for ‘No Deterioration’. This includes the potential to affect toxic contamination, organic loading, eutrophication, temperature, salinity, turbidity, and physical damage will need to be assessed alone and in combination with the other contributing permits via a Habitats assessment.

We would look to ensure any plans or proposals follow the Sewage Hierarchy, and that any necessary permits were in place before they are needed. We would also look to avoid proliferation of Package Treatment Plants by ensuring foul sewer and infrastructure availability. For water resources, we would recommend this should be part of enhanced pre-application.

Any proposed schemes in this area must consider the requirements of the legislation and be designed as to not adversely impact the estuary.

Developments within the vicinity of the Humber’s conservation designations are a concern for multiple stakeholders. For example, bathing water quality in this area is of high public and stakeholder interest. The capacity of sewage works must be considered at an early stage; surface water drainage, and pollution prevention actions should be overtly applied in accordance with best practice; trade effluent and cooling water be discharged consistently with other industries in the area and nationally; chemical and fuel storage should follow best practice.

6. Conclusions and Recommendations

We are already feeling the impacts of higher levels of greenhouse gases in the atmosphere on temperature and water. We must both limit climate impacts through rapid decarbonisation and adapt to this new reality for the industries and other users that depend on water.

This pathfinder project proactively addressed the government target of implementing a minimum of four low carbon industrial clusters by 2030 in line with the recently published Energy Security Strategy, by considering water needs and impacts in one location, in advance of planning and environmental permitting. These new processes will need to be deployed rapidly at scale and to avoid delay must consider current and future environmental capacity for low and zero carbon technologies. Potential challenges on development are critical to plan effectively for expansion of this ambition. Whilst some aspects of carbon capture and hydrogen production use established techniques from around the world, the proposed deployment of low and zero carbon technologies within the cluster have not been tested at commercial scale in the UK.

This project focused on the water requirements and impacts of the Humber Industrial Cluster due to its sizeable contribution of 12.4Mt to the UK's 33.2Mt total annual industrial carbon dioxide emissions. It also includes the highest number of current projects of approximately twelve, all with the potential to use water.

We developed and trialled a collaborative approach to explore the needs and impacts on the water environment of the proposed technologies in the Humber industrial cluster. We worked with local and national Environment Agency specialists, and key industrial and place maker stakeholders. Work included a literature review, a targeted stakeholder engagement exercise alongside consideration of known local environmental limits, climate projections and potential mitigation. In doing so the project trials an approach to support deployment of low and zero carbon technologies in all industrial clusters. The project demonstrates that there is a need and appetite for industry to have a consistent approach to understand and plan for environmental challenges with benefits for those involved.

In conclusion there is already significant pressure on water use in the Humber region from multiple users including industry, agriculture, and our own role to protect and improve the environment. Water quality is negatively impacted by multiple factors and suffers challenges to ecological status that need to be addressed. Looking to the future climate change projections (UKCP18) indicate that this situation will be worsened by climate change, that rainfall will significantly reduce over the summer months (34%) and we can expect greater incidence of droughts and low river flows by 2050.

It is difficult to forecast water use needs as many of the industrial cluster projects are both developing and complex, often involving both carbon capture and hydrogen production within the same proposal. But typical water usage figures for carbon capture, blue and green hydrogen plants indicate significant water needs. Whilst the emerging regional water resources plans for North and East England do recognise a likely increase in demand from technologies aimed at decarbonisation, there are many uncertainties due to the location, scale, and timing of developments within the cluster.

The proposals for low and zero carbon technologies are not consistent with current and future challenges to water in the Humber. The challenges these technologies present for water is a combination of existing known challenge for water use in the region and future limitations caused by climate change. There is likely to be competition between industries and other water users such as agriculture for the same water resource, whilst we in turn must meet our duty to protect and improve the environment.

Water use is likely to limit deployment of water intensive technologies south of the Humber. There is a high risk that these technologies won't deliver the required carbon dioxide emissions reductions or hydrogen production capacity in the short term (2025-2030) due in part to environmental challenges. Water demand must change if the assumptions about water use and impacts on water quality from the technologies proposed are correct. Developers of projects within the cluster should not rely solely on surface water and groundwater sources. There will be limitations on supply in specific areas within a region, both now and in the future.

How technologies operate, and what they will discharge to the environment must be fully understood at the earliest opportunity. Project design will need to be transparent, flexible, and incorporate multiple water sources, storage, and resilience options into their design. This may involve novel and collective approaches to developing water supply such as the treatment and reuse of effluents as an alternative to further direct or water company provided supply. The consideration of supply options should include long term supply viability for the expected lifetime of the project.

To secure sustainable supplies, water transfers from regions with a surplus may be needed. But this will result in higher transportation and carbon costs to industry. Without sustainable water resources being factored in at the planning and development stage the reduction in carbon emissions from low and zero carbon technologies may be offset by the need to transfer water into the Humber region.

Damage to the environment from unsustainable abstraction must be avoided. As suggested, there may be a future conflict between water demand for low and zero carbon technologies and nature restoration schemes resulting from the development of these technologies. They are less well understood compared to other sectors routinely regulated by us. As such our permit approaches for these technologies are less well developed. Barriers to effective regulation and authorisations include information availability.

The Humber is heavily protected for ecology and water quality including under WFD and habitats directives. Preventing the deterioration in classification and status of water bodies will be a significant challenge, the risk of abstraction-driven saline intrusion impacting on the water quality of the wider groundwater body, and thermal discharge plumes from cooling water causing eutrophication are two examples.

There is a need for consistency of approach across industrial clusters. Having a holistic strategy for water use, water quality and permitting in a more logical sequence would help minimise the burden on all players. This is especially important given the ambitious deployment timescales.

To provide a representative overview of environmental capacity in industrial clusters we recommend that this pathfinder project continue, to extend and build on the approach we have employed, to both the East Coast Cluster and one other industrial cluster. To explore the full spectrum of environmental capacity to assist decision-makers, industry and regulators and avoid costly delays in deployment.

Project extension recommendations:

- Expand and strengthen the technical scope of environmental capacity, to further consider water use and water quality, climate change resilience; emissions to air from hydrogen production and carbon capture technology, energy efficiency of low and zero carbon technologies, and public perception of environmental challenges.
- Explore opportunities for environmental enhancement, including how deployment can support existing environmental challenges in the intended location.
- Expand stakeholder engagement to include community group representatives, Health and Safety Executive, Natural England, UK Health and Security Agency, water, and power utility companies.
- Incorporate these factors and results into guidance for all industrial clusters that include carbon capture and hydrogen production.

This work will allow us to continue identifying limits of the current and future environment, to aid regulation and avoid costly delays in technology deployment. We will implement the successful approaches and lessons learnt in any extension, including how we engage, share, and collect information, to best explore environmental capacity and opportunities of deploying low and zero carbon technologies in industrial clusters.

Acknowledgements

The Environmental Capacity for Industrial Clusters project team would like to thank Environment Agency colleagues, industry, and place maker stakeholders for their important contributions and support to this path finder project.

Glossary

Abstraction license

The authorisation granted by the Environment Agency to allow the removal of water.

Best Available Techniques

Best available technology, as required under European Industrial Emissions Directive.

Blue hydrogen

Blue hydrogen is produced by splitting natural gas into hydrogen and carbon dioxide either by Steam Methane Reforming (SMR) or Auto Thermal Reforming (ATR), but the carbon dioxide is captured and then stored

Combined cycle gas turbines

Combined Cycle Gas Turbines are a form of highly efficient energy generation technology that combines a gas-fired turbine with a steam turbine.

Conservation designations

A conservation area is designated when the character or appearance of a place is considered special and worthy of preservation or enhancement. A designation gives a layer of legislative protection intended to ensure change is well-managed and the area's special sense of place is protected for future generations.

Consumptive water

Abstraction where a significant proportion of the water is not returned either directly or indirectly to the source of supply after use. For example, for the use of spray irrigation.

Cushion gas

The volume of gas that is intended as permanent inventory in a storage reservoir to maintain adequate pressure and deliverability rates throughout the withdrawal season.

Demineralised 'water'

Demineralised water is water which has been treated by one of several processes to remove dissolved minerals.

Desalination

The process of removing salt from seawater (saline water)

Discharges [direct and indirect]

The release of substances (for example, water, treated sewage effluent) into (a) surface waters – direct, (b) sewerage system – indirect.

Dispatchability

Dispatchability of generation refers to sources of electricity that can be used on demand and dispatched at the request of power grid operators, according to market needs.

Electrolysis Proton Exchange Membrane or Polymer Electrolyte Membrane (PEM)

Polymer electrolyte membrane electrolysis is a technique by which proton-exchange membranes are used to decompose water into hydrogen and oxygen gas. The proton-exchange membrane allows for the separation of produced hydrogen from oxygen.

Enhanced pre-application

The Environment Agency offers a chargeable in-depth advice, enhanced pre-application advice service for applicants prior to them applying for an environmental permit.

Environmental capacity

Natural resources or air, land and water characteristics that are sensitive to changes that may require conservation or remediation measures, or the application of creative development techniques to prevent degradation of the environment, or may require limited development, or in certain instances may preclude development.

Gasification

A process that converts biomass- or fossil fuel-based carbonaceous materials into gases, including as the largest fractions: nitrogen, carbon monoxide, hydrogen, and carbon dioxide.

Green hydrogen

Hydrogen generated by renewable energy or from low-carbon power.

Hands-off flow measurement

A condition attached to an abstraction licence which states that if flow (in the river) falls below the level specified on the licence, the abstractor will be required to reduce or stop the abstraction.

Heat transfer medium

A solid, liquid and/or vapor phase which can be used to store heat in a reversible form and can be circulated within the installation, e.g., in pipes

Joint Environmental Programme (JEP)

JEP supports a programme of research into the environmental impacts of electricity generation funded by seven of the leading producers in the UK.

Low carbon technologies

Innovative technical solutions characterised by low emission intensity of greenhouse gases compared to existing technology.

Low river flows

Q95 (the flow of a river which is exceeded on average for 95% of the time i.e., low flow)

‘No Deterioration’ policy

The permitting of a discharge into a water body will cause some localised deterioration. The deterioration from one status class to a lower one is not permitted.

Organic Rankin Cycle (ORC) engines

An ORC uses an organic, high molecular mass fluid with a liquid-vapor phase change, or boiling point, occurring at a lower temperature than the water-steam phase change. The fluid allows Rankine cycle heat recovery from lower temperature sources. The low-temperature heat is converted into useful work, that can itself be converted into electricity.

Pre-Front End Engineering Design (pre-FEED) stage

FEED is an engineering design approach used to control project expenses and thoroughly plan a project before a fix bid quote is submitted. Pre-FEED is the stage leading up to the final FEED submission.

River Basin Management Plan

River basin management plans set out the legally binding objectives, standards, and measures to meet water objectives for all sectors of our economy. We are determined to accelerate our progress and drive the actions that are needed forward.

Rough Reservoir

A former natural gas storage facility situated off the east coast of England.

Steam Methane Reforming

Steam reforming or steam methane reforming is a method for producing syngas (hydrogen and carbon monoxide) by reaction of hydrocarbons with water. Commonly natural gas is the feedstock.

Sustainable Urban Drainage Systems (SUDs)

A collection of water management practices that aim to align modern drainage systems with natural water processes.

Syngas

The resulting gas mixture from a gasification process.

System Efficiency

In this example, a percentage of the energy produced in the form of hydrogen at the HHV compared to the amount of electrical energy input.

Thermal discharge

In this context, thermal discharge is the discharge of heated water into bodies of water.

Thermal plasma electrolysis

The use of atmospheric pressure plasmas located between the electrode tips and the water surface to electrolyse the water producing oxygen and hydrogen.

Water Resources East (WRE) / Water Resources North (WReN)

Two of five regional groups responsible for delivering a Regional Water Resources Plan in line with the National Framework for Water Resources. They are both partnership a from a wide range of industries, including water, energy, retail, the environment, land management and agriculture working together to safeguard a sustainable supply of water for the East and North of England

Water resources management plan (WRMP)

The statutory 25-year plans that all water companies in England & Wales are required to update, publish, and consult on every five years. The plans show how companies intend to secure water supplies for current and future customers, at least cost to customers, society, and the environment, while meeting all other environmental obligations

Appendices

To be added as separate document once complete – available on request