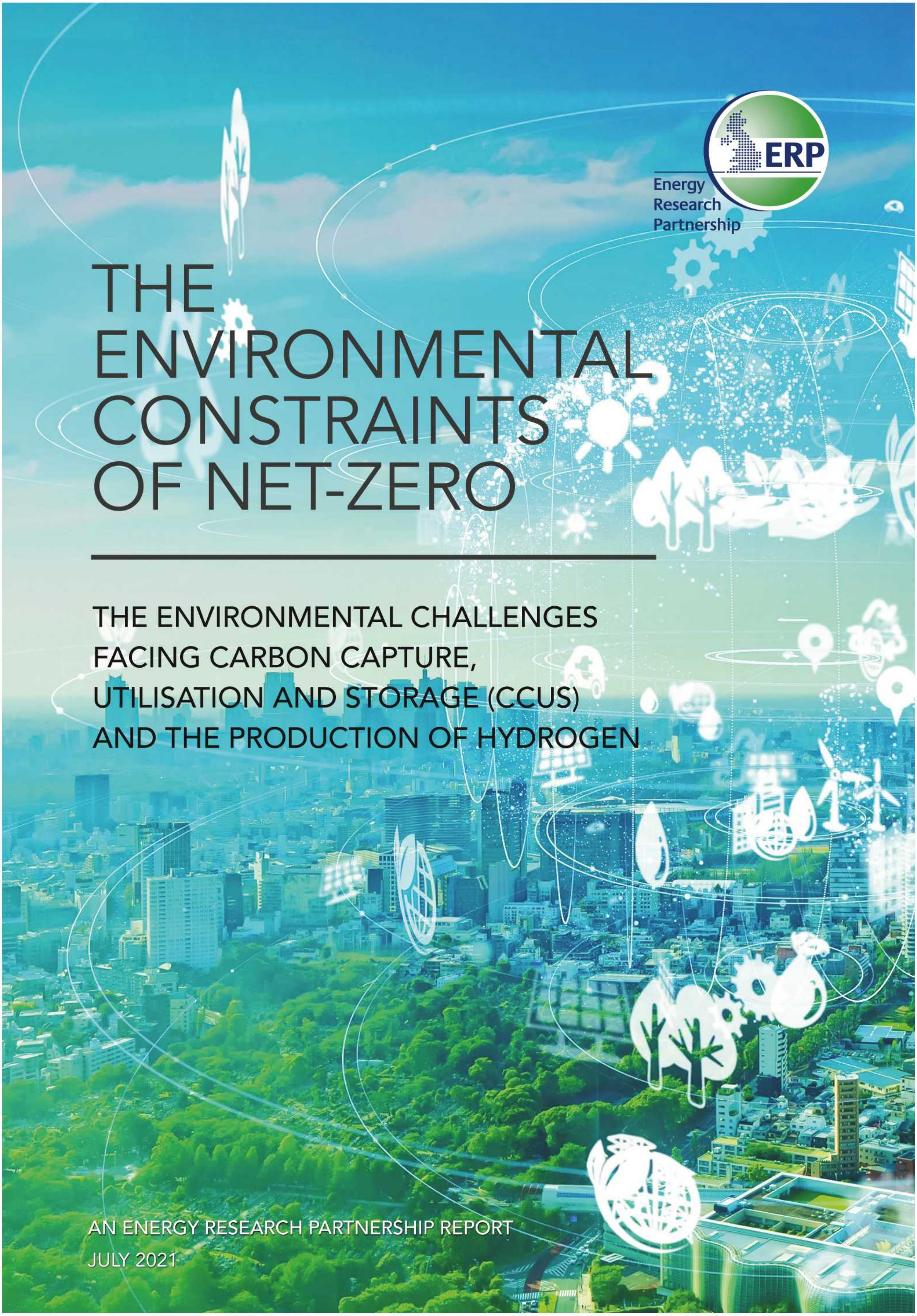

# THE ENVIRONMENTAL CONSTRAINTS OF NET-ZERO

## THE ENVIRONMENTAL CHALLENGES FACING CARBON CAPTURE, UTILISATION AND STORAGE (CCUS) AND THE PRODUCTION OF HYDROGEN

AN ENERGY RESEARCH PARTNERSHIP REPORT
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ENERGY
ELECTRICITY
TECHNOLOGY
ALTERNATIVE

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# 1. INTRODUCTION

**In October 2020, the Energy Research Partnership brought together key industry, academic and government stakeholders to discuss the environmental constraints of net zero focussing on CCUS and Hydrogen. The plenary set out to review environmental constraints as strategic considerations of all deployments of low and zero carbon technologies, not just those in regional clusters.**

The Prime Minister's Ten Point Plan for a Green Industrial Revolution (November 2020) set out a specific ambition to invest in and support the development of low and zero carbon technologies. It is expected that a range of new technologies relating to the decarbonisation of the energy and industry sectors to emerge at scale between now and 2030 with a specific focus on hydrogen and CCUS.

Whilst there is some uncertainty as to whether hydrogen and CCUS can be deployed at scale in a cost-effective way in the 2030's, the industry view is that the technical challenges may not be insurmountable. However, there are a number of environmental factors that will require research and strategic thinking to sustainably deploy low and zero carbon technologies. Any future energy mix will also need to protect air, soils and water and an environment already threatened by a changing climate.

Public interest in the low and zero carbon energy sector is growing, awareness of carbon capture was 46% according to the latest Public Attitudes Tracker, compared to 36% in 2012 (BEIS Public Attitudes Tracker 2020). Public perception of emerging technologies will likely focus on safety and the environment with an expectation of openness and transparency. There are indications that the public are opposed to the continuation of fossil fuel extraction for energy, even with associated carbon capture and storage.

The Industrial Decarbonisation Strategy, and the Energy White Paper are recently published documents from the government that set out the pathway for the UK to meet the target of Net Zero carbon emissions by 2050. A Hydrogen Strategy is due to be published in 2021 setting out the ambition to deploy hydrogen production at scale.

| Colour | Primary Feedstock | Primary Energy Source | Primary Production Process | Carbon Impact (kg $CO_2$/kg $H_2$ |
|---|---|---|---|---|
| Brown | Coal or Lignite | Chemical Energy in Feedstock | Gasification & Reformation | 18 to 20 |
| Grey | Natural Gas | Chemical Energy in Feedstock | Gasification (SMR) | 10 to 12 |
| Blue | Coal, Lignite or Natural Gas | Chemical Energy in Feedstock | Gasification with Carbon Capture and Sequestration | 0.6 to 3.5 |
| Green | Biomass or Biogas | Chemical Energy in Feedstock | Gasification & Reformation | 0 |
| | Water | Electricity | Electrolysis | |
| Pink | Water | Nuclear Power | Electrolysis | |

Figure 1: Carbon impact of hydrogen production

# 2. EXECUTIVE SUMMARY

This report looks at the important considerations that energy infrastructure and decarbonisation technology need to be built with a strategic view of environmental constraints in mind. It may seem inevitable that technology will be constrained by specific environmental factors such as air quality, water availability for cooling, capture efficiency, and emissions of residual carbon dioxide from carbon capture, however this may not be the case for every development.

Public perception of climate change and carbon emissions is changing. The public are forming their view on the role of CCUS in our future energy mix. The latest evidence suggests they are unsure if CCUS is safe for the environment (Climate Assembly UK 2020) and the majority do not favour it.

Why are environmental constraints on CCUS processes - production, transportation, storage and use of carbon dioxide - and the production, storage, transportation and use of hydrogen important? Can we deploy these technologies at scale in the UK and protect our communities and wildlife? Could our air, land and water be affected? Can we move and store carbon dioxide and hydrogen safely and for the long term? This report looks to raise important environmental considerations associated with these questions.

- What are the main environmental challenges associated with CCUS and Hydrogen?
- Do environmental constraints represent a fundamental barrier to deployment of CCUS and Hydrogen at scale?
- How can we ensure environmental considerations are key to strategic decisions about the potential role of CCUS and Hydrogen?
- How do we listen to and respond to public concern about CCUS and Hydrogen?

The Energy Research Partnership considers that environmental constraints will pose a challenge to the deployment of low and zero carbon technologies at commercial scale. These technologies are promising but environmental challenges will create obstacles on the path to deployment and need to be looked at now on a commercial scale to understand the potential of these technologies, alongside other forms of electricity generation.

## 2.1 Report recommendations

1. **Explore whether water resource and quality issues will limit deployment of CCUS at scale.** Drive efficiencies in water use for hydrogen and carbon capture at commercial scale, use the multi-sector framework of regional water resources groups to balance the needs of the sector and other water users. Prioritise water efficiency for process and cooling water in plant design and emphasise the need to research the availability and security of water abstractions. Ensure water quality is considered alongside water availability.

2. **Put safety of the public and the environment first.** Prioritise research into the assessment of emissions from carbon capture and the potential impact on air quality. Assess the environmental fate of capture solvent emissions. Assess human health risks and air quality impacts, agree standards for amines and their degradation products.

3. **Be open and transparent about risks, including solvents.** The public will not accept the technology if they do not understand the risks, or they suspect risks are being hidden from them. Regulators cannot properly assess risks without clarity and openness from the industry. To build trust in this new technology a position of disclosure by default should be adopted.

4. **Calculate total efficiency of the complete CCUS process.** Account for and report the efficiency of all associated processes from extraction of natural gas through to the long-term storage of carbon. This will present real world performance figures and report residual carbon dioxide emissions of the whole process.

5. **Calculate the total expenditure (Totex) cost of CCUS.** The water industry uses a total expenditure (Totex) model for new assets. For CCUS to be successful, the total cost for construction, operation, maintenance and regulatory controls must be considered equally when calculating funding and investor returns.

6. **Demonstrate carbon dioxide storage is safe and permanent.** Account for the safety risks of carbon storage and address concerns through robust monitoring of subsurface carbon dioxide storage locations. A better understanding is required of the environmental impact of the direct sea disposal of aquifer brines with potentially high concentrations of contaminants.

7. **Proactive and visible public engagement.** Make proactive public engagement the mainstay of communications and adopt the outcomes from public perception dialogue projects. Engage with current research into public perception studies to gather insight and learning from dialogue with communities living near industry clusters.

# 3. ENVIRONMENTAL CONSTRAINTS AND NET ZERO

To create a sustainable and socially acceptable sector around low and zero carbon energy generation that can create a smoother pathway to 2050, action is needed to address the potential risk of impacts on natural resource, air quality and water quality that can influence public attitudes.

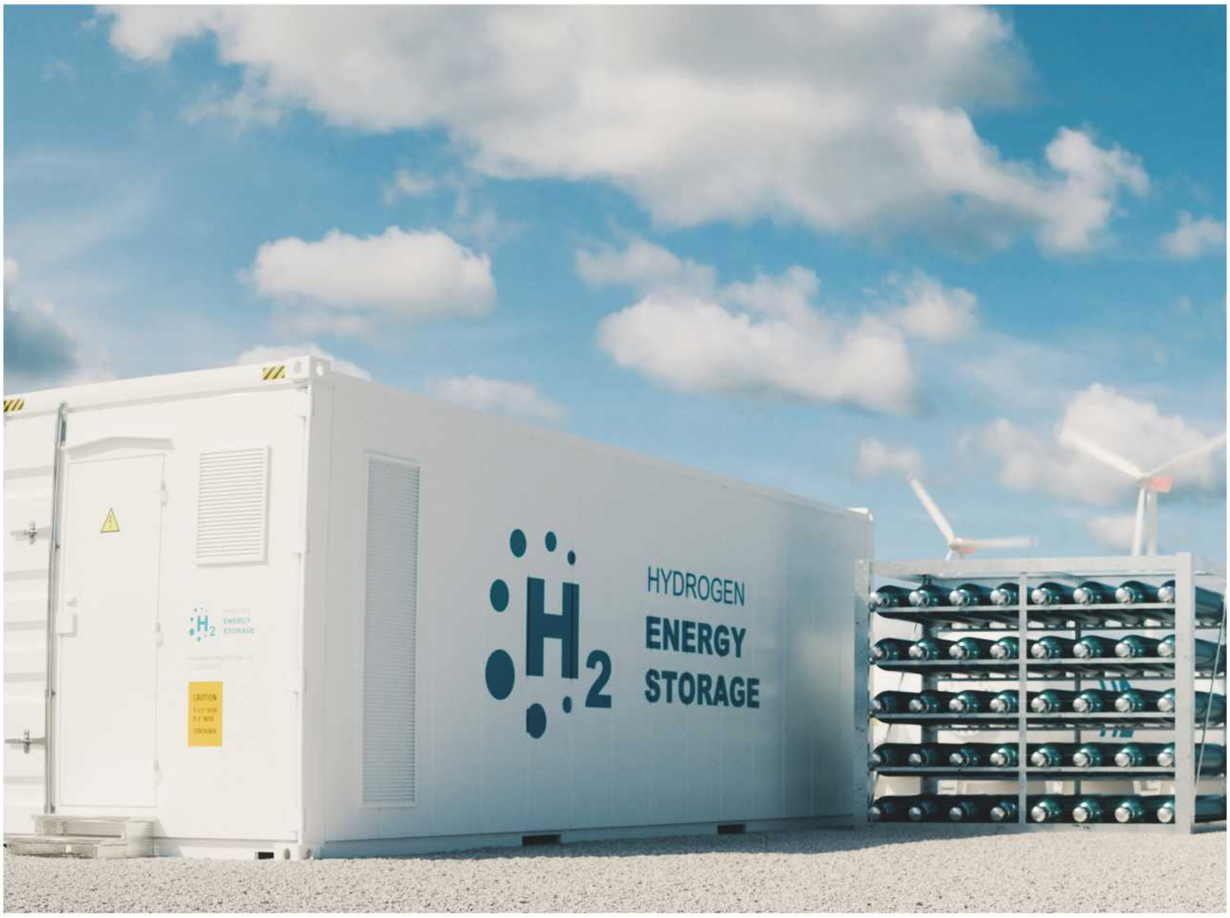
According to the Institute for Government, a significant proportion of the population have not heard of or know very little about Net Zero (Institute for Government 2020). This emphasises the need for public engagement, particularly around the issues of concern such as environment and safety. The number of technologies promoted by government to achieve the Net Zero 2050 target, and earlier targets set for 2030, are set to grow, leaving public attitude as a priority area on which to focus engagement.

# 4. THE DEPLOYMENT OF CARBON CAPTURE, STORAGE, AND HYDROGEN IN THE UK

By 2050, CCUS deployment in the UK is anticipated to be made up of clustered locations and individual (dispersed) developments, the geographic location is often set by previous industrial activity, proximity to high carbon dioxide emitters, and the availability of a transportation network for onward sequestration of carbon dioxide. For dispersed high emitters, the location is determined by the industrial process and its proximity to a source of raw materials, or raw material imports that include industrial sectors such as iron & steel, cement, and oil & gas refining.

The location of hydrogen production on the other hand is anticipated by application, whether hydrogen for heat or for fuel, with a suitable transport network for the high-volume producers.

Consideration of the impact placed on these locations from an air quality perspective, and the increase in demand for raw materials and natural resources is very important.



# 5. CARBON CAPTURE STORAGE, AND HYDROGEN AND ENVIRONMENTAL CONSTRAINTS

The examples discussed here will be a challenge to the development of these technologies. Environmental constraints may shape deployment despite a combination of engineered solutions, strategic planning, and sustainable operation that could mitigate effects.

The possible constraints listed here stem from the evidence available on the environmental risk associated with Hydrogen and CCUS technologies and may be applicable to other new energy technologies.

# 5.1 Water resource

Climate change means extreme weather patterns, hotter and drier summers, drought conditions, wetter winters, some parts of England will see further water supply deficits. The need to balance water demand for public water supply, industry, and biodiversity is becoming even more important. The third UK Climate Change Risk Assessment (UKCCRA3) due to be published in summer 2021, will assess the impacts of climate change now, and predict future impacts.

Water demand will be one consideration in the design of hydrogen and carbon capture plants, along with location, and water efficiency of the capture process. Water demand for carbon capture will vary between capture processes and carbon dioxide removal expectation placed on the plant from a cluster of producers.

Hydrogen and carbon capture can use freshwater or sea water, or a combination of both for cooling purposes, as well as a raw material in the capture process. Water for cooling is not essential but the more water that can be made available for cooling the more cost effective the process can be.

In England one third of the electricity generated using freshwater cooling is in areas classified as over-abstracted. For example, in Water Resources East region (which includes the river Trent), the current licensed daily consumptive abstraction of freshwater for power generation is about 120 Ml/d. Under some scenarios for 2050, daily freshwater consumption could reach 600Ml/d (hydrogen pathway), 500Ml/d (electric pathway) or 400Ml/d (hybrid pathway). Ref JEP (RWE UK) 2020: Scenarios for the projection to 2050 of Water Use by Power Producers – with a focus on WRE.

Technical solutions included in plant design and strategically located infrastructure will need to play an important role in addressing the challenge of water availability versus demand. Locating the majority of once through cooling (the most efficient) for power plant on the coast or in tidal estuaries, using non-fresh water sources has been standard practice for decades. It could be argued that carbon capture plant might be best placed on the coast if cooling and carbon dioxide transport were the only considerations. For inland plant, tower/hybrid cooling with fresh water or air cooling should be considered, though the latter is up to 3% less efficient than once through cooling. Constrained by a lack of water, plants will need to adapt at a cost of additional engineering.

Alongside the available technical solutions, a multi-sector framework of regional water resources groups can work together to balance the needs of the sector and other water users. Ref Policy paper March 2020: Meeting our future water needs: a national framework for water resources.

In practice it's a societal choice as well as an environmental necessity as to how the available water resource is used and how much it will cost to reach net zero. Clearer communication using authorisation consultations, such as Development Consent Orders (DCOs), local planning, environmental permits, water abstraction licences, will assist public understanding.

## 5.2 Water quality

Consideration will need to be given to the risk of potential ecological impacts as a result of commercial scale hydrogen and carbon capture deployment. For example, thermal pollution from cooling waters poses a risk to vulnerable species of fish and aquatic organisms as warm water depletes oxygen levels, altering the ecology in rivers, estuaries, and marine ecosystems. Whilst coastal deployment may resolve the water availability issue there is a risk of operational impacts associated with estuarine water temperatures. As river and sea temperatures rise (as a result of already locked-in climate change) then the operational constraints necessary to protect ecosystems will also increase. To minimise this impact designers, developers and operators should consider climate risks when designing CCUS processes – ensuring they are fit for the future. The risk to the aquatic environment from industrial pollutants is also a factor, regardless of the sector.

The proximity of new development to designated habitats may present an additional challenge. Power generation infrastructure close to ecologically sensitive receptors is not unusual in the UK but it is important to point out these potential risks of additional impacts.

# 5.3 Emissions and monitoring

Amine-based solvents are commonly used in carbon capture processes. When amines are released, the formation of nitrosamines and nitramines occur, both are possible carcinogens (SEPA 2015). The emissions of amines and their degradation products from the post-combustion carbon capture method, which involves the removal of carbon dioxide from stack emissions after combustion of fossil fuel, is an area of research looking to understand the implications of releasing amine compounds to air, and through wastewater discharges.

The post-combustion carbon capture process releases amines to air, and wastewater. When amines are released degradation products such as nitrosamines and nitramines are formed, creating a hazard for people and the environment as both are possible carcinogens. Much needed research in this area is underway, without it our understanding of these emissions on air quality may leave us vulnerable to impacts.

In order to protect human health and the environment, Environmental Assessment Levels (EALs) or Environmental Quality Standard (EQS) thresholds are needed to assess the risk to human health from these degradation products. Thresholds are particularly important for developers to determine the requirement to abate these emissions before release to the environment and inform the regulator through permit determinations to assess environmental impact.

For regulators to impose emission limits, and developers to design abatement systems, atmospheric dispersion models need to predict not just the impact from one emission source, but the cumulative effect of multiple emission sources. Put simply, we need to understand now what the risks are of Hydrogen and CCUS deployed at the commercial scale imagined by industry and government. Much of the information in this area is new, studies that will model and assess emissions from capture plant will be critical to the development of plant.

Background levels of amine and their degradation products are unknown in the UK. The assessment of ambient amines for locations where developments are planned will be needed to contribute to the production of threshold levels. Currently, the position in the UK is to adopt the international environmental thresholds in the absence of national thresholds (SEPA 2015).


Projects in the planning and authorisation phases don't have the benefit yet of knowing the latest standards for the UK, developers will need to remain agile to the changing landscape in emissions monitoring and reporting standards, otherwise developments will be at risk of delay or authorisations could be refused.

# 5.4 Data & Information

The disclosure of data and information to the public is important in the development of these technologies, however it can be closely linked to public perception. The reassurance required to the general public on safety and environmental risks will grow. Regulators have a duty to disclose information to the Public Register, however the chemistry of capture solvents are considered by industry as intellectual property. Industry may argue a competitive disadvantage if solvent chemistry for carbon dioxide capture became freely available.

Rules on disclosure of environmental information to the public register include all information in relation to emissions to the environment, though operators of plant can apply to the regulator for information to be considered Commercial in Confidence (CiC).

Freedom of Information Regulations (FoI), Scot FOSIR, is used by the public and media to request environmental information under the Freedom of Information rules. Few exceptions to the rules exist, for example, information that if disclosed would be contrary to the interest of national security, details on the construction of injection wells for geological sequestration, and details of the geology sampled during well construction.

Without disclosure of this type of information to the regulator determination timescales of authorisations are compromised, applications may be rejected due to insufficient information to assess the impact on air quality. Public confidence in the technology may be affected, resulting in lost support from local communities.

Clear policy on robust advice to industry is required, clarifying existing guidance on the disclosure of environmental information to the public register and how it will apply to them. Setting out this expectation ahead in the planning process of a development will avoid delays with authorisations. Industry must play their part by being open with regulators and the public.

# 5.5 Application of Best Available Techniques (BAT)

Clear guidance is being developed with stakeholders on the regulatory requirements for hydrogen production and CCUS including BAT. In the determination of BAT, the economically and technically viable techniques which are best for preventing or minimising emissions and impacts on the environment as a whole (DEFRA 2021) are considered.

BAT guidance for Hydrogen production from methane and refinery fuel gas, and Post combustion carbon capture has been prioritised, influencing the design, and operation of plants. As the guidance is being developed in response to the imminent deployment of these technologies, industry need to engage with BAT guidance development on plant design and operation.

Participation by industry in consultations on the development of guidance is key to help shape standards and drive improvements in areas such as emissions monitoring, pollution prevention, and resource efficiency. **All Hydrogen and CCUS developments will be advised to follow this guidance. It is strongly recommended that industry consult with environmental regulators during the design phase of a project.** Without proper consultation, opportunities will be missed to incorporate standards into plant design early. A lack of adequate reference to BAT may result in delays in the environmental permitting process.

# 5.6 Energy & capture efficiency

There is uncertainty over achievable carbon dioxide capture rates, the value of carbon capture technology is dependent on the ability to efficiently capture carbon dioxide, a 90% removal rate or below reduces the value of this technology as an abatement option (CCC 6th Carbon Budget, Dec 2020). An industry target of 95% or above by 2050 would limit the residual emissions but may incur an energy penalty, increasing the cost of removal and resulting in a less competitive option to alternative electricity generation.

Considering the carbon dioxide capture efficiency of a plant is not enough, for a complete picture, accounting for and reporting the efficiency of plant operation and the carbon dioxide generated that needs capturing, would provide a more accurate indication of emissions reduction.

Industry must be ready to account for and report the capture efficiency of their processes to present real world performance figures and calculate the residual carbon dioxide emissions that will need to be offset. This is equally important when gas CCUS is used in support of renewables, emissions from start-up and shut-down gas CCUS would need to operate without leading to an increase in residual emissions and costs (AECOM 2020).

Blue hydrogen with CCUS produced from methane reformation is likely to be the most common form of hydrogen production until a transition towards green hydrogen is achieved. Blue hydrogen as a fuel for electricity generation has the potential to provide support to renewables and nuclear during peak demand. Hydrogen in this application has the potential for long duration energy storage in order to meet seasonal peaks in electricity demand, though long term storage can bring high costs (Climate Change Committee 2018). As an electricity generation alternative this option provides the power sector with low carbon emissions over the whole lifecycle. Though the advantages of using hydrogen as a back-up electricity generator are known, the lifecycle energy requirements for methane reformation when renewable energy is not available, along with storage and transport must be taken into consideration.

Without accurately accounting for and reporting performance figures on capture efficiency in a developing sector, confidence in technology to operate sustainably and provide the highest carbon dioxide removal rate possible will be low.

# 5.7 Monitoring subsurface carbon dioxide storage locations

In accordance with the EU Directive on carbon dioxide geological storage, the fundamental objective is to ensure the environmentally safe storage of carbon dioxide. The future of carbon capture and storage will be determined by the safe storage of carbon dioxide free of impacts on the environment.

The risks associated with carbon dioxide geological storage can include, leaks through well barrier loss, natural barrier breaches, or poor storage reservoir management. Robust long-term reservoir management and monitoring is key to safe, permanent storage of carbon dioxide in saline aquifers and depleted oil and gas fields.

The management and monitoring of geological carbon dioxide storage has been advancing around the world, however, further research is needed on whether the carbon dioxide injection in saline aquifers and depleted fields and the extraction and reinjection of aquifer brines as a reservoir pressure management technique have any environmental impact. Unpublished research suggests that the direct disposal of brines to the water column may only cause very localised salinity and temperature mediated impacts, but if high concentrations of contaminants exist within brines, this may instigate larger impacts.

A large body of work exists estimating environmental impact potential on the marine ecosystem from a wide range of release scenarios, based on real world release experiments and subsequent modelling. Small releases in the order of 1T/d, such that could be imagined resulting from bore hole type seeps, have been shown to have very restricted impact (order of a few meters from source). Impact potential scales with release rate such that catastrophic failures of storage, where release to the surface was a significant proportion of injection rate, would be environmentally damaging.


A requirement for the determination of appropriate geological characterisation and sub-surface monitoring is essential to prevent catastrophic failures, demonstrating that permanent geological storage is safe and low risk.

# 5.8 Public perception

High profile actions around the climate emergency is increasing public awareness of Hydrogen and CCUS. Nine UK CCUS public dialogue projects have been organised since 2012 to track public opinion. These projects have engaged a diverse and inclusive group of the public in conversation about the future use of Hydrogen and CCUS technologies. The latest public perception dialogue results are due in 2021. According to the latest data, 46% of the population have some awareness of CCUS (BEIS Public Attitudes Tracker), an increase of 41% since March 2020. A UK Climate Assembly report states that 56% of members disagreed or strongly disagreed with continued use of fossil fuels with carbon capture. The opinion of the public is that CCUS only provides a short-term and expensive solution when better renewable alternatives to electricity generation are available.

Informing the public can start earlier than directed by public consultations during the authorisations process. The Development Consent Order (DCO) requires applicants to carry out a two-stage public consultation on their projects, a similar requirement exists for environmental permits. Despite this reassurance of public participation, participants of the latest CCUS public perception dialogue held in November 2020 were unaware of this opportunity.

An uncertain feeling from the public may mean that a 'social licence' is needed in the safe and sustainable deployment of Hydrogen and CCUS. There may be lessons to learn from the onshore oil and gas experience. A policy of openness and transparency is needed to generate public support.

# 6. CONCLUSION

As with many emerging technologies, Hydrogen and CCUS provides exciting opportunities and pose new challenges too. The UK Government and the Climate Change Committee both see a significant role for hydrogen and CCUS in the journey to Net Zero by 2050. To ensure this opportunity is grasped, then collectively the industry, government, and regulators must explore both the benefits and risks the technology brings at the earliest opportunity. We are facing a climate emergency and an ecological emergency – it is essential that new technologies are deployed to both deliver decarbonisation and protect people and wildlife too. Investors, regulators, and the public are hungry for assurance that new technologies:

- will be fit for the future when deployed at scale.
- they can operate within the environmental constraints a future climate brings.
- and most importantly, human health is prioritised.

**It is strongly recommended that industry consult with environmental regulators during the design phase of a project. Without early engagement with regulators, opportunities will be missed to incorporate standards into plant design early which may result in delays in the environmental permitting process.**

**By resolving these questions in a prompt, open and transparent way then developers can build investor confidence and public acceptance of the technology which will be needed to improve the prospects of a smooth energy transition towards Net-Zero.**

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