Environmental Capacity in Industrial Clusters

Phase 4 Technical Annex 2 - Overview of stakeholders, method and responses

Date: 25th February 2025

Version: 0.3

Prepared by:

Patrick Froggatt
Technical Air Quality Director
AECOM

On behalf of:

Environment Agency
Horizon House, Deanery Road,
Bristol BS1 5AH

www.gov.uk/environment-agency

Contents

Abbreviations

APIS	Air Pollution Information System
AQEG	Air Quality Expert Group
AQMAU	Air Quality Modelling & Assessment Unit
AQS	Air Quality Strategy
AURN	Automatic Urban and Rural Network
BAT	Best Available Technique
BECCS	Bioenergy with Carbon Capture and Storage
BP	British Petroleum
CC	Carbon Capture
CCGT	Combined Cycle Gas Turbine
CCS	Carbon Capture and Storage
CCSA	Carbon Capture & Storage Association
CCUS	Carbon Capture, Utilisation & Storage
CHP	Combined Heat & Power
CO_2	Carbon Dioxide
COMAH	Control of Major Accident Hazards
DAC	Direct Air Capture
DCOs	Development Consent Orders
Defra	Department for Environment, Food & Rural Affairs
DESNZ	Department for Energy Security and Net Zero
EA	Environment Agency
EAL	Environmental Assessment Limit
EET	Essar Energy Transition
EfW	Energy from Waste
EIR	Environmental Information Regulations
ELV	Environmental Limit Value
EPR	Environmental Permitting Regulations
ERF	Energy Recovery Facility
ETS	Emissions Trading Scheme
EU	European Union
FEED	Front End Engineering Design
FOI	Freedom of Information Regulations
GEP	Good Engineering Practice
GIIP	Good Internation Industry Practice
GW	Gigawatt
H_2	Hydrogen
H_2S	Hydrogen Sulphide
HRA	Habitat Regulations Assessment
ICI	Imperial Chemical Industries
INCA	Industry Nature Conservation Association
kgN/ha/yr	Kilogrammes of Nitrogen per Hectare per Year
LNG	Liquefied Natural Gas
LCP	Large Combustion Plant
LCOH	Levelized Cost of Hydrogen
LOD	Level of Detection
MEA	Monoethanolamine
MW	Megawatts
N_2O	Nitrous oxide
NDA	Non-disclosure agreement
NE	Natural England
NGN	Northern Gas Network
NH_3	Ammonia
NO_x	Oxides of Nitrogen
NO	Nitrogen Monoxide
NO_2	Nitrogen Dioxide
NPL	National Physical Laboratory
HyNet	Consortium of low carbon technology projects in the North West of England.
OCGT	Open Cycle Gas Turbine
OEM	Original Equipment Manufacturer
OTNOC	Other Than Normal Operating Conditions

PC	Process Contribution
PM_{10}	Particulate Matter less than 10 µm in diameter
$PM_{2.5}$	Particulate Matter less than 2.5 µm in diameter
ppb	Parts per billion
ppm	Parts per million
R&D	Research & Development
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
SCR	Selective Catalytic Reduction
SNCR	Selective Non-Catalytic Reduction
SPA	Special Protection Area
SSSI	Site of Special Scientific Interest
TAG	Technical Advisory Group
UK	United Kingdom
UKHSA	UK Health Security Agency
WHO	World Health Organization

Introduction

This document provides an overview of the Environmental Capacity in Industrial Clusters project Phase 4 workshops conducted with stakeholders involved in industrial decarbonisation within the region of the HyNet industrial cluster. Building upon Phase 3, the workshops focused on emissions challenges, technical feasibility and permitting complexities associated with low-carbon technologies. The findings aim to inform strategic and operational decision-making for sustainable industrial practices.

Engagement Methodology

Online meetings and workshops were conducted between November 2024 and January 2025 inclusive. The meetings lasted 1-2 hours. Meetings with industrial stakeholders, the local authorities, Environment Agency (EA) officers, the UK Health Security Agency (UKHSA) and Natural England (NE) in the HyNet area comprised a presentation delivered jointly by the EA and AECOM, followed by breakout for discussion of key questions adapted to the stakeholder(s).

The objectives of the engagement were to:

- Gather stakeholder insights on air quality and emissions impacts from planned decarbonisation projects.
- Identify knowledge gaps in emissions monitoring, cumulative impacts and permitting challenges.
- Explore industry perspectives on regulatory compliance, solvent use and technical feasibility.
- Assess infrastructure constraints (e.g., hydrogen distribution, CO_2 pipelines) and policy barriers affecting project implementation.

The approach to the Phase 4 workshops differed slightly to that taken for the Phase 3. During Phase 3 a greater focus was placed on undertaking workshops with trade associations, i.e. the Carbon Capture & Storage Association, Energy UK, Hydrogen UK and the Hydrogen Energy Association, with a few select industrial stakeholders consulted individually.

While the wider trade organisation workshops provided very useful insights into the wider concerns of industry and the current and future state of the industry, they provided only limited input on air quality and future emission impacts within the area of study. Due to this and the short time since the trade organisations were last consulted, the Phase 4 workshops took a different approach to focus primarily on individual industrial stakeholders with sites located within the HyNet area.

Discussions in the workshops followed a structured format, with questions tailored to each stakeholder group. Key topics included:

- The anticipated impacts of low-carbon technologies on air quality, particularly concerning NO_x, ammonia, amines and novel emissions.
- The feasibility and challenges of emissions monitoring, including gaps in data collection and the development of Environmental Assessment Levels (EALs) for new pollutants.
- The role of permitting requirements in influencing technology selection, particularly regarding solvent choices for carbon capture.
- Infrastructure needs, such as hydrogen distribution and CO_2 pipeline capacity and how they affect project feasibility.
- The suitability of current regulatory frameworks and potential adaptations to better facilitate industrial decarbonisation.

Meetings were recorded with participants' permission and a transcript was generated. The following summaries are based primarily on the transcripts. In some cases, the transcripts failed to accurately record technical language with the recordings used to confirm the accuracy of the transcripts and correct them as required.

All information provided during the meetings has been taken in good faith and has not been independently verified. Workshop participants were notified at the start that the information provided would be summarised and form an appendix to the HyNet report. A copy of each workshop summary was provided to the participants to allow them the opportunity to review and amend the summary before the production of this Annex. This also allowed participants to provide further information, which a few participants did take advantage of, following the workshops/meetings.

Stakeholder Meeting Summaries

Regulators

Environment Agency Internal Workshop - 25/11/2024

Current Baseline

The main area of concern focused on air quality issues associated with the deployment of amine-based carbon capture and storage (CCS). Key concerns included the lack of baseline information on amine and amine degradation product concentrations, limited monitoring techniques and insufficient data on proprietary solvents other than monoethanolamine (MEA). These issues are linked to human health and ecological receptor impacts, particularly due to nutrient nitrogen deposition from aerial dispersion and the lack of information on the impacts on habitats. To address these impacts, permits require applications to include nutrient nitrogen contributions from amines using conservative ammonia deposition rates, despite limited research being available.

Alternative solvents, such as Shell CANSOLV, are being considered as they have lower amine emissions and so are likely to contribute less to nitrogen deposition compared to MEA. This is because amine emission rates from proprietary solvent formulations are likely to be more restricted by the environmental permit to consider other hazards and minimise risk to human health. Some information on proprietary solvents is now publicly available in the environmental register. Development of Environmental Assessment Levels (EALs) for seven amines is underway, with consultations expected in early 2025.

Permitting

The need for solvent disclosure and transparency in chemical composition was emphasised, alongside maintaining confidentiality for proprietary information. Current permitting frameworks lack mechanisms for efficiently publishing solvent emission data, although all relevant information is technically available in public registers. Without established Best Available Techniques (BAT) standards for these technologies, operators rely on existing guidance, such as good engineering practice (GEP) and Good International Industry Practice (GIIP), which does not fully address environmental and health risks associated with new solvents. Additionally, manufacturers focus on efficiency and effectiveness in terms of carbon capture performance, but this may not be the best for human health and ecological receptors.

There are other challenges faced by current applicants include noise impacts (Viridor Runcorn) and propriety solvent confidentiality (Padeswood).

<u>BAT</u>

Potential future challenges for several developments include the need for a permit variation for solvent changes which require public consultation with a revised BAT assessment, air quality impact assessment and noise assessments. Commentators noted that BAT standards cannot be developed by the regulator until more carbon capture plants are in operation and more performance data is available, the UK BAT Standards Council will decide when this point is.

<u>Future Developments</u>

Projects to be aware of include the Essar Vertex/Essar Energy Transition (EET) Blue H_2 (permitted), Protos Encyclis Energy from Waste (EfW) (in determination) and Viridor Runcorn (in determination).

The need to check ammonia production or hydrogen production from imported green ammonia was highlighted as it can contribute to additional ammonia and hydrogen emissions and flaring of ammonia. Direct Air Capture (DAC) could potentially use amines as solvents in the long term, this is not currently regulated under the Environmental Permitting Regulations (EPR).

<u>Future technology</u>

Research for technology to improve air quality shows carbon capture acid wash has an impact on reducing ammonia (and amine) emissions to air through atmospheric chemistry and dispersion modelling of secondary emissions from carbon capture.

Cumulative Effects

Potential cumulative ecological impacts were discussed, particularly regarding amine contributions to nitrogen deposition. The HyNet cluster's proximity to sensitive ecological sites, such as the Mersey Estuary Special Protection Area (SPA), Ramsar and Site of Special Scientific Interest (SSSI), increases the urgency for robust cumulative impact assessments. Background nitrogen deposition levels already exceed critical load ranges for these areas, underscoring the need for industry collaboration to mitigate impacts.

Human Health Impacts

Current information on the impacts of carbon capture, utilisation & storage (CCUS) on human health are uncertain, assessments have been submitted, Essar Vertex/EET Blue H_2 is a closed system with no emissions to air, Protos Encyclis EfW and Viridor Runcorn are in determination and the assessments need validating to confirm the modelled emission levels are feasible. These sites are not located in close proximity however the Ince Bioenergy with Carbon Capture and Storage (BECCS) proposed site is adjacent to Protos Encyclis, therefore cumulative impacts may present a higher risk.

Ecological impacts

The contribution of amines to nitrogen deposition on ecological sites is currently unknown and there are no critical levels available for amines for site operators and regulators to assess amine impacts against.

The HyNet cluster is next to the Mersey Estuary SPA, Ramsar and SSSI. Checks of the Air Pollution Information System website (APIS) indicate that the lowest nutrient nitrogen deposition critical load range for the:

- Mersey Estuary SPA is 10-20 kgN/ha/yr for Saltmarsh Habitats.
- Mersey Estuary SSSI is 5-10 kgN/ha/yr for Raised and Blanket Bogs.

Nitrogen deposition backgrounds are > 15 kgN/ha/yr in many parts of the Mersey Estuary SPA, Ramsar and SSSI, so background nitrogen deposition exceeds the critical load ranges stated above.

Other Comments

A public solvent library was proposed to centralise data on solvent performance and emissions. This could aid regulators and industry stakeholders in aligning carbon capture technologies with both environmental and health priorities. Emerging technologies, such as carbon capture acid washing, were highlighted for their potential in reducing ammonia and amine emissions.

Feedback emphasised the need for continued research on cumulative impacts and the development of predictive tools for human health and ecological risks. Future permitting may include stricter requirements for disclosure and mitigation strategies.

Monitoring

There is a proposal for temporary background monitoring in HyNet area (industry/Local Authority sponsored) but no regular or ongoing monitoring is currently in place.

Solvent disclosure

Guidance and training workshops have been provided to the Carbon Capture & Storage Association (CCSA) and Energy UK trade bodies to highlight the need to specify the solvent, alongside pre-op advice and briefings for carbon capture industries in response to claims for commercial confidentiality via the CCSA. Information should not be withheld from the public register relating to emissions (as required under Freedom of Information Regulations (FOI), Environmental Information Regulations (EIR) and EPR). Full disclosure on chemical names of all substances present in the adsorption and abatement towers are required to review emissions assessments. Applications withholding information on propriety solvent composition will be considered but emissions will not be kept confidential. Solvent components and breakdown products present in adsorption and abatement towers will not be held confidential unless the applicant can demonstrate these cannot be emitted. Briefing notes on this can be found: Amines including Commercial Confidentiality.

Key knowledge Gaps

Emissions to air:

- There is a lack of evidence related to solvent emissions for carbon capture plants provided by solvent suppliers. The provided data, either theoretical or where monitored, comes from pilot plants which are not comparable to the carbon capture plants to be permitted. Detailed projected emission profiles are required for carbon capture plants to be permitted, and this lack of actual data represents a limit when trying to validate the application emissions assessment.
- There is no validated methodology for monitoring ammonia, amine and n-amine emissions with the emission of many of these pollutants being below the current Level of Detection (LOD). This makes it hard to determine the appropriate Emission Limit Value (ELV) or to assess how stack emissions compare to ELVs where in place. The EA is currently working with the UK National Physical Laboratory (NPL) to develop stack monitoring techniques.
- There are EALs published for only a limited number of amines and their associated breakdown products. As such there is the need to develop/improve EALs related to carbon capture plants, and the EA needs to work with the UKHSA to develop these.
- There is currently no tool available to assess the contribution of amine emissions on nutrient nitrogen deposition. There is also uncertainty related to air dispersion modelling software and how it is used to predict n-amine concentrations.
- There is currently no predictive risk assessment tool to assess the cumulative impacts of carbon capture plant emissions on human health and ecology in cluster

developments. This limits the assessment of the cumulative impacts of NO_x, ammonia, amines and n-amines deposition on nutrient nitrogen and subsequent ecological effects.

- Other pollutants of concern may include non-amine solvent components used in carbon capture and carbon dioxide from pipeline venting during installation, maintenance and operation.

Amine and breakdown product fates:

- There is currently no approved wastewater treatment methodology for dealing with the residuals from acid-wash waters used to mitigate amine emissions from carbon capture plants. Currently, these wastewaters are classed as hazardous waste and, as such, incineration is recommended.
- There is a lack of understanding of the deposition of amines/n-amines from carbon capture plants to surface waters. There is an ongoing Norwegian study to establish a methodology which can be applied to calculate nitrosamines deposition rates onto surface water bodies to be used within human health risk assessment. This study is titled “Future Drinking Water Levels of Nitrosamines and Nitramines near a CO_2 Capture Plant (FuNitr)”. It aims to deliver tools applicable to CO_2 capture technology, however no results are available from this study yet.
- There are currently no Environmental Quality Standards (EQS) for amines/n-amines against which water quality impacts can be assessed which means that the impact of discharges of contaminated wastewater to surface waters cannot be assessed.

Other:

- Operators who sign non-disclosure agreements (NDAs) with proprietary solvent suppliers have no awareness of solvent contents, hazards in use, emissions potential etc.
- There is currently no BAT or GEP guidance related to carbon capture emission mitigation meaning that there is no fixed method for reducing emissions to air, e.g. acid washing, etc. This limits the enforcement of mitigation measures increasing the potential for cumulative impacts, especially in clustered developments. There is, therefore, a need to gather and develop evidence to support the development of GEP and BAT guidance.

<u>Policy</u>

On 15th October, the Department for Energy Security and Net Zero (DESNZ) released its Consultation Response on Decarbonisation Readiness (DR) for Power, outlining how it will be implemented based on feedback. The Environment Agency has been given a new duty to ensure decarbonisation readiness in power generation.

From 28th February 2026, operators applying for new or significantly upgraded EPR permits must submit a decarbonisation readiness plan. This plan should outline how they will transition to low carbon technologies, such as carbon capture or hydrogen conversion. A Statutory Instrument to update the EPR is expected in the coming weeks. Following this, the Environment Agency will conduct an external consultation on draft guidance for EPR applications, anticipated early next year.

Notes on emissions not previously discussed:

- If emissions for EfW and Large Combustion Plant (LCP) are monitored upstream of the carbon capture absorber they are likely to overestimate NO_x emission concertation at the stack as some NO_x is removed in carbon capture abatement.
- The energy penalty for running carbon capture is high (likely >27%). If operators meet the increased energy demand by adding a new combustion plant, consuming more fuel or processing higher volumes of waste in Energy-from-Waste (EfW) facilities, overall site emissions may increase.
- Some energy generation practices (EfW, BECCS, LCP) will likely require increased use of Selective Catalytic Reduction (SCR)/Selective Non-Catalytic Reduction (SNCR) which has associated increased ammonia emissions.

Local Authority Workshops - 19/11/2024 and 29/11/2024

Current Baseline

Both workshops highlighted significant gaps in criteria to assess the human health impacts of amine degradation products. Monitoring efforts currently focus on stack testing, leaving ambient background concentrations largely unexamined. Concerns about nutrient pollution, also referred to as nutrient pollution, via aerial deposition were central, emphasising the challenges in controlling nutrient deposition and its potential to limit future developments. However, it was noted that air quality assessments are conservative and there are other control options available including acid washing. While air quality assessments were identified as being conservative, they were considered necessary for assessing/managing impacts. Historical industrial activity in areas like Ellesmere Port has left a legacy of poor air quality perceptions, further amplified by ongoing controversies over industrial emissions and planning decisions.

Challenges

Local authorities noted the difficulties in addressing the fragmented nature of industrial cluster developments. The reliance of multiple schemes on interconnected assessments exacerbates resource and personnel challenges. Economic constraints, limitations in technical expertise and public opposition to hydrogen use in domestic settings were identified as barriers. Shifting local attitudes remain difficult, especially without robust government policies on decarbonising domestic fuels. Government support for heat networks was also highlighted as a challenge for the uptake of domestic hydrogen use along with infrastructure costs, infrastructure challenges for the existing network and how hydrogen fits within these networks for existing and new developments.

Hydrogen Supply and Storage

A modular approach to hydrogen supply and storage was discussed in the context of Control of Major Accident Hazards (COMAH) regulations and environmental permitting. Concerns were raised about safety distances for hydrogen storage facilities and proximity to residential properties. Challenges associated with expanding existing sites and developing new ones were also explored.

Public Perception

Participants emphasised the importance of proactive communication and monitoring to address public opposition. The potential for hydrogen uses in a domestic setting was discussed, highlighting that this was the main area of local opposition rather than industrial use and there will be difficulties changing local attitudes on this. The cancellation of the domestic hydrogen trial in Ellesmere Port highlighted the need for effective engagement strategies. The growing support for heat networks was noted as progressing faster than hydrogen infrastructure, complicating integration efforts.

Planning Opportunities

Updates to local planning documents were highlighted as a potential avenue for industries to better align decarbonisation efforts with regional policies. These updates present opportunities for collaboration between local authorities and industry stakeholders to address shared challenges and improve public trust.

UK Health Security Agency & Natural England Workshop - 16/12/2024

Current Baseline

The workshop highlighted the impacts of industrial clusters on sensitive ecological sites, focusing on cumulative effects assessed through different planning routes (DCO and Town and Country Planning Act). Manchester Moss SSSI and Holcroft Moss were identified as particularly sensitive areas, already addressed through strategic solutions outlined in relevant plans due to combined impacts and triggering of APIS levels.

Evidence Gaps

Current understanding of the ecological impacts of carbon capture and hydrogen production technologies remains limited. These gaps hinder mitigation discussions from a Habitat Regulations Assessment (HRA) perspective.

Literature reviews on evidence gaps and impacts of these technologies, completed for Natural England's internal use, were suggested as resources that could potentially be shared with the EA after quality assurance.

Monitoring and Permitting

The workshop discussed monitoring requirements for additional pollutants and amine degradation products, highlighting ongoing deliberations about the best methods to enable effective monitoring. The permitting process was reviewed to emphasise the need for mitigation measures tailored to individual applications and pre-application engagement to ensure applicants understand key issues. However, the time-intensive nature of engaging across numerous schemes was acknowledged.

Other Comments

Participants noted the importance of clarifying mitigation options within the permitting context. Collaboration between Natural England and other stakeholders was encouraged to streamline permitting and assessment processes.

Industry

Viridor – 21/11/2024

The Mersey Estuary SSSI and blanket bogs were highlighted as sensitive ecological sites. Raising the question of outdated ecological surveys, designations of sensitive for whole areas based on a small part of the designation and site maintenance to promote these sites. This was also raised as a potential issue for future permit application restrictions.

Viridor are currently within a 13-month Front-End Engineering Design (FEED) design of a 25-year operations carbon capture system on their energy from waste plant. The main challenges to date concern the site layout of the new technologies. Cooling systems requirements with rising temperatures due to global warming were not highlighted as a concern, these are designed to be as efficient as possible incorporating existing cooling at the facility and a safety factor in the design. No acid wash is required of the flue gas prior to carbon capture in the initial feed design.

Viridor have a current permit application with MEA as the solvent in the determination stage to act as a permit in principle. This is proposed to be updated in March 2025 with a permit variation to a propriety solvent provided by a commercial partner. The air quality assessment for the permit deemed emissions as acceptable for the proposed development and cumulative operation. Viridor highlighted concerns with the permit variation on what information is required to be in the public domain and challenges with solvent disclosure.

Other concerns were:

- future capacity of the CO_2 pipeline and if it will be sufficient to allow later adopters of Carbon Capture technology to connect; and
- absence of government/environment agency policy on air emission offsetting and the role that this could play in mitigating emissions from installations which are unable to eliminate their direct emission to air and subsequent impacts on ecology.

Carlton Power - 22/11/2024

Carlton Power supplies green gaseous hydrogen, with its customers (off-takers) responsible for the combustion of hydrogen and the associated emissions. Carlton Power emissions to air include oxygen venting as it is currently not economically viable to capture, process and sell the oxygen produced, emergency venting and fugitive emissions related to hydrogen supply to clients via pipeline or tanker, where a pipeline is not a feasible option.

Limitations of oxygen capture include the lack of commercial use, the complexity of technology in capture and transportation and the commitments and volume requirements from industry. Hydrogen venting in emergency scenarios is possible, however, the units are designed to minimise this. Traffic emissions associated with tanker movements are considered to be minimal, a 15 MW project would require a supply of 4 tankers per day, which contributes minimal carbon dioxide emissions in comparison to the combustion of natural gas. The supply of hydrogen to consumers via a pipeline is the preferred option, however, this is location, distance and demand dependent, with road transport via tanker used in the absence of a distribution pipeline.

Challenges highlighted by Calton Power clients on decarbonisation include downtime for technology changes. For example, CCGT units switching from 100% natural gas to 100% hydrogen may require almost a complete rebuild of the plant and take a period of two to three years. While this sort of investment may be worthwhile for some installations, for others, especially for smaller companies, the cost and prolonged period of downtime are not economically feasible. As such there is a need to balance decarbonisation and air quality improvement against the impact on business or run the risk of sites closing as they cannot afford to decarbonise.

The challenges of hydrogen supply include limitations of renewable electricity supply, Carlton Power uses grid connections and manages renewable energy supply through plant sizing, hydrogen storage and reduced exposure during peak energy demand. Economic and commercial challenges include factors linked to compliance with Levelised Cost of Hydrogen (LCOH) standards to ensure the production and sale of hydrogen is economically viable and client commitment requirements of 15 years for commercial viability. An additional challenge is ensuring economies of scale, aggregating smaller users as a site would need a high demand to justify their own unit. Carlton Power aims to have physical assets on the ground and in full operation generating green hydrogen by 2027.

Tata Chemicals – 27/11/2024

The main limitations highlighted in the discussion and included in detail below include the industry's requirement to change processes, the commercial viability of the alternative options, limitations of alternative fuel supply and associated risk, permitting limitations and associated additional complications investing in UK plants.

Tata are currently undertaking a number of changes and optioneering for future development processes. CO_2 is required as a raw material in Sodium Bicarbonate production, therefore the combustion of natural gas is required. The aim of the process is to maximise the CO_2 yield and carbon capture for use in pharmaceuticals and food-grade products. Blending hydrogen within the natural gas grid is, therefore, a concern for Tata Chemicals as it will reduce the amount CO_2 that is generated and so available for use by subsequent processes (pharmaceuticals and food-grade products).

The main options to decarbonise these areas include:

- carbon capture, using MEA, on low NO_2 boilers,
- switch to hydrogen combustion – limitations identified include supply and NO_x emissions; or
- fully electrify the process - however this is not commercially available due to UK energy costs.

Concerns with permitting propriety solvents were discussed, these solvents offer higher capture efficiencies and lower energy requirements, however, the perceived limitations for permit approval remain an issue. In Europe there appear to be fewer issues associated with solvent disclosure as these companies engage directly with regulators to provide detailed data, highlighting a different approach to the UK.

Currently, MEA is the only solvent being considered due to the risks associated with permit approval, limited understanding of propriety solvents and prior knowledge of operating a carbon capture with this amine-based solvent. Tata Chemicals highlighted that newer proprietary solvents have benefits, despite the unknowns associated with their composition and breakdown products, including offering reductions in the amount of energy needed in their reformation compared to MEA.

There is the potential to decarbonise through process changes. The production of synthetic soda ash is no longer deemed economically viable due to the energy intensity. Therefore, soda ash production will be ceased and natural ash sourced by a sister company in the US will be used as the raw material. There is the potential to import CO_2 if the demand can't be met, however, this adds another element of risk.

An area of concern for the uptake of carbon capture in the industry is the limitations of the current policy published by DESNZ and the Emissions Trading Scheme (ETS) for industries looking to utilise CO_2 in their processes. Currently, if carbon is captured at one site, tankered to the sodium bicarbonate site and emitted as part of this process it is considered to be emitted twice and Tata is charged twice. Under current policy the use of carbon in this form is not considered to be true sequestration. The driver for change to decarbonise these processes is shareholders rather than policy or commercial incentives. Additionally, there are currently no incentives in place for the production of green sodium bicarbonate.

Amine degradation chemistry was highlighted as an area of concern for monitoring, dispersion modelling and human health impacts. The variations and limitations of dispersion modelling were highlighted due to different reaction kinetics used in modelling assumptions, different flue gas compositions, current understanding, the overprediction of cumulative effects and wet and dry deposition. The monitoring of amine degradation products is a technical barrier and Tata is willing to support the EA in local monitoring linked to the Winnington site.

Tata highlighted the design of any carbon capture they propose will include acid scrubbing; the need was highlighted through experience with the current site.

Concerns with in-house hydrogen production and combustion include technological limitations and uncertainty, high cost, supply risk, combustion efficiency, solvent and catalyst requirements, different pollutant emission issues, permitting uncertainty and longevity of cost protections (currently 15 years under hydrogen business model). Additionally, due to the scale of the sites blue hydrogen would be required for generation, green hydrogen isn't considered sustainable at this scale and has high water demands.

Encyclis - 29/11/2024

Encyclis have received a draft permit for their incinerator with carbon capture based on MEA solvent with acid and water washing treatments.

Constraints highlighted within the permitting process include the conservative approach required for the air dispersion modelling, where incinerator emissions, amine emissions and amine degradation product emissions are modelled at maximum concentrations even when these scenarios could not happen simultaneously. MEA is the permitted and intended solvent for this development due to the timelines associated with the Track 1 competition and the EA position on challenges of permit approval with proprietary solvents at the time of submission. During long-term operation this may change depending on the market and a permit variation would be required. There are constraints in the process around the level of detail of the process information required by the EA permit team during the permit applications and operation of the facility, including what information can be shared in the public domain.

Potential issues on carbon capture include the energy requirements for operation; thermal output could be limited by the size of the boiler and this could impact plant efficiencies. The venting of carbon dioxide during start-up and emergency scenarios was discussed as part of the permit application, in the context of posing a risk to human health. This had no additional risk to the environment as it would be releasing what is currently released through the existing Energy Recovery Facility (ERF) stacks through a dedicated CO_2 vent stack which is set at a similar height to the ERF flue stacks. Due to the timescale of start-up for incinerator plants the capture and storage of CO_2 is not possible. This is typically limited to 1 planned outage per year, with an estimated 4-5 unplanned scenarios.

The offset of emissions with current agriculture emissions was discussed with the reduction of farming activities and the impact on local food production was highlighted as an issue. A reduction of agricultural emissions rather than purchasing and ceasing farmland activities was highlighted as a potential offsetting opportunity based on a presentation given to CCSA members in 2023.

A carbon capture plant in Holland was discussed which is used to supply carbon dioxide to greenhouses for ~6 months at a time. Limitations of this plant are the efficiencies of carbon capture demonstrated, which does not achieve the EA BAT capture requirements of 95% as it was designed to only capture a proportion of the CO_2 generated and the quality of the CO_2 captured which does not achieve the purity limits required for acceptance by the HyNet Carbon Dioxide Transportation and Storage project.

Kraft Heinz - 13/12/2024

Kraft Heinz are aiming for 50% decarbonisation by 2030 and carbon net zero by 2050. Some steam generation has been converted to heat pumps to reduce carbon dioxide emissions. Feasibility studies are in progress for achieving net zero considering hydrogen combustion and fuel switching, heat pumps and gasification of steam. Electrification is not considered an option in the near future due to energy requirements which are predicted to double in the next 5-10 years.

The boilers at the Kitt Green site are suitable for hydrogen blend combustion with the potential for 100% hydrogen combustion with alterations. Concerns include the difficulties in scaling green hydrogen and the ability to meet requirements, carbon capture emission risks and NO_x emissions and potential abatement requirements for hydrogen combustion.

Carrington 19/12/2024

Carrington are considering hydrogen combustion for decarbonisation, the hydrogen pipeline will run to Partington as part of Cadent Phase 2 pipeline planning 2026. Carbon capture is not currently being considered as the pipeline is not planned to reach the site. Carrington has recently undergone feasibility studies to use hydrogen or hydrogen blends in their gas turbines. The gas turbine is a Saldo Legacy Ulster GT26 with two combustion chambers. The Original Equipment Manufacturer (OEM) confirmed a natural gas hydrogen blend is possible with the current system due to the two combustion chambers allowing greater control over the temperature and combustion process.

Gas Turbine Feasibility

Three hydrogen blend scenarios were examined:

- 0-20% hydrogen blend – No modifications to the current system are required.
- 20-45% hydrogen blend – Would require system updates. These upgrades are generally offered to older gas turbines to improve efficiency; however, the GT26 turbine is already at the higher end of its specification, so this modification is not currently planned.
- Above 45% hydrogen – Not currently in development. Achieving this level would require a new gas turbine, which is presently unfeasible due to market constraints and limited hydrogen availability.

Testing of up to 45% hydrogen blends has been conducted in Europe at the European Space Centre, where a test rig was set up to replicate a combustion chamber. The results indicate that 45% hydrogen can be achieved without water cooling or additional NOx abatement.

However, technical challenges at this level include:

- Lean blowout risks at low temperatures.
- Flashback risks at high temperatures.
- The need for higher pressures to mitigate these risks.

Pipeline Feasibility

Carrington currently receives natural gas via a 2km underground welded pipeline. While an in-depth pipeline leakage assessment has not been conducted, leakage risks have been highlighted, particularly at small-bore instrumentation, valves and gaskets. These areas may require modification to safely transport hydrogen.

Additionally, the hydrogen pipeline will operate at 70 bar, with an offtake at 35 bar, while the gas turbine requires a minimum of 47 bar. This discrepancy means that hydrogen will need compression before blending with natural gas, but mixed gas compressors are currently not financially viable.

Safety and Equipment Considerations

Hydrogen leakage was identified as a significant safety concern, requiring careful hazardous area management. The feasibility study found that hydrogen-compatible materials would be necessary to ensure the safe operation of the infrastructure.

Emissions and Environmental Considerations

A key challenge associated with hydrogen combustion is the potential increase in NOx emissions, which currently stand at 42 ppm. Additional abatement strategies are required to ensure compliance with permitted emission levels. Water injection abatement is being considered instead of Selective Catalytic Reduction (SCR) due to space constraints in the heat recovery steam generator.

Hydrogen combustion at 80-90% hydrogen would create high water demand for temperature control and NOx abatement. This excess water is released through cooling towers, which may affect plume visibility.

Carbon Capture Feasibility

Carbon capture is not being considered at Carrington due to the absence of a local pipeline connection. Additionally, amine regeneration is highly energy-intensive and not suited to the plant’s flexible operational requirements. The site is required to balance renewable energy sources, meaning it must adjust its operation in response to fluctuating energy demand. Maintaining this flexibility, ensuring quick adjustments to power output while remaining efficient and reliable, makes a carbon capture system impractical..

Policy and Financial Considerations

The driver for decarbonisation is government funding and Clean Power 2030. However, there are concerns over the government’s hydrogen-to-power business model, as it focuses on 100% hydrogen use, which is not feasible with current technology at Carrington.

Evero - 19/12/2024

Evero has two sites under development, the most advanced is the Index Project at the Inspire Power Plant in the Protos area, in which a carbon capture facility is being added to the current power plant. Completion of the pre-FEED is scheduled for January 2025, process design is planned for Q1 with the FEED following in March. FEED tendering is currently ongoing. Planning is scheduled for submission in May-June. Following pre-app meeting with the EA, permitting is ongoing but required outputs from the feed work that are expected to be submitted in December. The project is expected to become operational in 2029. A two-permit approach is being taken, one is a permit variation for the original site to allow for new equipment and raw materials within the current boundary and the other is a new permit for the carbon capture facility. An air quality impact assessment will be undertaken for the carbon capture facility permit. The other site is the Widnes plant which will also have carbon capture and is 6 months behind the Index project and is expected to become operational in 2030.

The carbon capture plants are being designed for use with a Mixed Hydrogen Reforming (MHR) technology propriety solvent due to increased capture efficiency. Discussions have been undertaken with the EA to understand the information requirements for permitting.

Current concerns include permitting limitations, the knowledge gaps on cumulative impacts and amine and amine degradation product background concentrations.

Permitting challenges include the requirement to share proprietary solvent information, which is currently being actively discussed between the project developers, technology companies and the EA. Additional challenges include the quantity and complexity of permit applications in this area and the potential impact on project timelines. This will be managed as much as possible through forecasting based on stakeholder feedback and pre-app discussions between industry and EA, increasing understanding pre-app of the information required to reduce follow-ups.

The uncertainty on limits for degradation products and cumulative impacts have been identified as a potential risk early in the permit application process. This is linked to the lack of information on baseline and ambient levels of amines and amine degradation products, the unknown cumulative effects and the point at which these move from negligible to impactful and the consequence of this. It was noted that discussion and research on monitoring options and an internal investigation on the cumulative impacts on air quality from low carbon technologies are ongoing by the EA. An additional point for future research was raised on impact assessments, assessing different pollutants against one EAL rather than individual EALs.

Fugitive emissions were highlighted as a concern area after public consultation between the developer and community linked to the emissions of CO_2 from the plant and pipeline.

Progressive Energy - 20/12/2024

The challenges discussed include prioritisation of essential industry, permitting, modelling limitations, pipeline and storage capacity, future scenarios, cumulative impacts and new pollutant emissions.

The challenge of prioritising critical infrastructure considering environmental capacity and changes to headroom for different pollutants linked with emissions offsetting in these locations was discussed. This links to difficulties in permitting and capacity when ensuring the development of critical infrastructure. Earlier adopters of low-carbon technologies may find the permitting process easier due to a lack of background information on pollutants and a reduced cumulative effect. At present, industry stakeholders adopting these technologies do not consider this a major concern, as they are primarily focused on overcoming more immediate barriers, such as securing financing for their projects. Until these projects reach the FEED and detailed design stages and planning and permit application processes, they may not be aware of the limitations and risks due to air quality. This may be valuable information to provide during early FEED design to justify technology decisions and discuss guaranteed emission values. This could be supported by an increased understanding of the background levels of these emissions, receptor sensitivity and impacts, specifically for nitrogen deposition. Additional concerns with increased numbers of permit applications and variations on the EA's workload, potentially leading to extended determination times before approval.

Limitations to modelling were highlighted, specifically, the capability of Gaussian models traditionally used for these assessments in the UK for assessing cumulative scenarios., suggesting other tools such as Calpuff that may be more suitable. This highlighted the potential for a review of modelling techniques and methodologies in the future. It was noted that the EA are currently working on modelling industrial clusters and developing data on these emissions.

A pressure point on the development of future schemes is the capacity of the systems proposed for storage and pipeline transport. The current capacity for carbon capture accounts for Track 1 developments but may become a system limitation for future developments. The method of hydrogen production, availability, distribution and storage will also determine future development and the type of schemes carried forward. If there are government delays to funding for large-scale hydrogen generation with carbon capture, production may shift to focus on smaller-scale green hydrogen within existing industrial sites for decarbonisation. There is uncertainty on how and which of these technologies will support clean power by 2030 and depends on the region and hydrogen availability.

Additionally, fugitive emissions of hydrogen were discussed as a potential concern to decarbonisation as hydrogen is a greenhouse gas.

Emphasis was put on the need to maintain a 'digital twin', a real-time virtual model of planned and approved projects, alongside ongoing analysis after project approval. This would provide a comprehensive understanding of which developments are moving forward and help assess their cumulative impacts. However, a key limitation identified was the challenge of keeping the digital twin up to date, particularly given the extended timelines and uncertainties surrounding project decisions. The responsibility for maintaining this system could fall to project developers, regulators or an industry-led collaboration to ensure transparency and coordination.

Ineos - 06/01/2025

Ineos have a permitted 200MW electrolyser at the Runcorn facility, currently producing 10,000 tonnes of green hydrogen a year and are involved with the Viridor Carbon Capture Project. The hydrogen produced on-site is also used by a third party, uses includes boiler and innovation and a boiler and is transported by road trailers.

Ineos are currently tendering for FEED studies to cover storage, water and brine infrastructure and aim for solution mining, a process that involves injecting water into underground salt formations to dissolve the salt and create caverns for hydrogen storage, by 2027 and hydrogen storage by 2030. A permit application is in preparation to change the brine cavern storage facility from natural gas to hydrogen. Ineos identified the HYPSTER project as a relevant European-funded research initiative that could inform their work on subsurface hydrogen storage. The project involves the commissioning of a demonstration hydrogen storage facility, which is expected to provide valuable data on hydrogen storage in a salt cavern.

Hydrogen storage in salt caverns requires large compression into caverns which contain a pool of brine to make saline conditions to reduce moisture. The storage facility plans to use a solid desiccant to remove moisture. The hydrogen requires regeneration through dehydration before entering the network by heating using electrical energy from the grid, i.e. no on-site natural gas/hydrogen combustion will be required. There is no planned hydrogen combustion for power generation on-site and emissions of NO_x and ammonia are not expected.

Concerns include government-driven delays to policy and supporting legislation which could affect current timelines, hydrogen sulphide (H_2S) formation in storage and high-water levels at abstraction points. A government announcement before Christmas delaying the hydrogen storage business model could potentially impact timelines, but is not currently affecting timescales.

There are numerous ongoing studies on the formation of H_2S in subsurface hydrogen storage related to bacteria. This is currently an unknown area but with increased studies more information on this will become available.

The risk of climate change due to flooding and high-water levels of abstraction rivers has the potential to damage equipment, this is a facility design consideration and climate change risk assessments are required.

Hydrogen venting of stored material is not of great concern, generally for a downhole issue the base safety is to keep the hydrogen in the salt cavern. Flaring and associated emissions would only be expected for releases at the surface or when depressurisation of the plant is required.

Conclusions and Recommendations

Based on the Phase 4 workshops conducted for the HyNet industrial cluster, several key themes and recommendations have emerged to guide future decarbonisation efforts:

- Establish robust baseline monitoring for amines, ammonia, nitrosamines and fugitive hydrogen emissions to address data gaps and develop appropriate EALs.
- Develop a framework for assessing cumulative ecological and air quality impacts, particularly in sensitive areas like the Mersey Estuary SPA, to prevent future project limitations.
- Expand hydrogen distribution networks and CO_2 pipeline capacity to meet the needs of current and future decarbonisation projects, ensuring scalability and efficiency.
- Implement iterative and collaborative permitting processes to address the complexities of emerging technologies and ensure timely project approvals.
- Invest in advanced abatement technologies, such as water injection and acid scrubbing, to mitigate NO_x and ammonia emissions from hydrogen combustion and carbon capture.
- Streamline regulatory approval processes for proprietary solvents while maintaining transparency and public accountability to reduce delays and enhance operational flexibility.
- Design infrastructure to withstand climate-related risks such as flooding and rising water levels, particularly for hydrogen storage and CO_2 transport facilities.
- Foster collaboration among regulators, local authorities and industries to address shared challenges in emissions, permitting and public acceptance.
- Implement targeted communication strategies to address public concerns about hydrogen and CCS technologies, ensuring transparency and fostering trust.
- Advocate for policy incentives and financial support to accelerate the adoption of low-carbon technologies, including hydrogen production, electrification and carbon capture systems.