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Accelerating Low carboN Industrial Growth through CCUS

Deliverable Nr. D5.1.1

Summary of outcomes of TVCA planning for the Teesside industrial CO_2 capture cluster relevant to the offshore transport and storage network

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Executive summary

This UK case study regarding the industrial cluster at Teesside focuses on assessing the UK's prolific storage potential to reduce the cost of CCS, not only for the UK, but also for countries around the North Sea Basin. There are many aspects to accelerating industrial CCS that are covered elsewhere in the ALIGN-CCUS Project study, but this study specifically focuses on transport and storage network development in the North Sea area. This report is an update to ALIGN Deliverable 5.1.1a which provided an interim summary of TVCA's Teesside planning.

The North Sea Basin between the UK and Norway is particularly well mapped due to half a century of oil and gas industry seismic surveys, drilling, production data and sub-surface modelling activities. The UK with 80 gigatonnes and Norway with 70 gigatonnes have similar, high confidence (75-100%) mapped carbon dioxide (CO_2) storage volumes, but UK water depths are generally shallower than Norwegian water depths. In addition, the sub-surface drilling depths of many suitable storage sites are shallower than other parts of the North Sea Basin. Hence, the CO_2 injection wells can be both drilled and maintained, over their multi-decade lifetimes, at lower cost in UK waters. With 27% of Europe's high confidence total CO_2 storage potential, the UK can provide a cost-effective CO_2 storage service to the North Sea Basin.

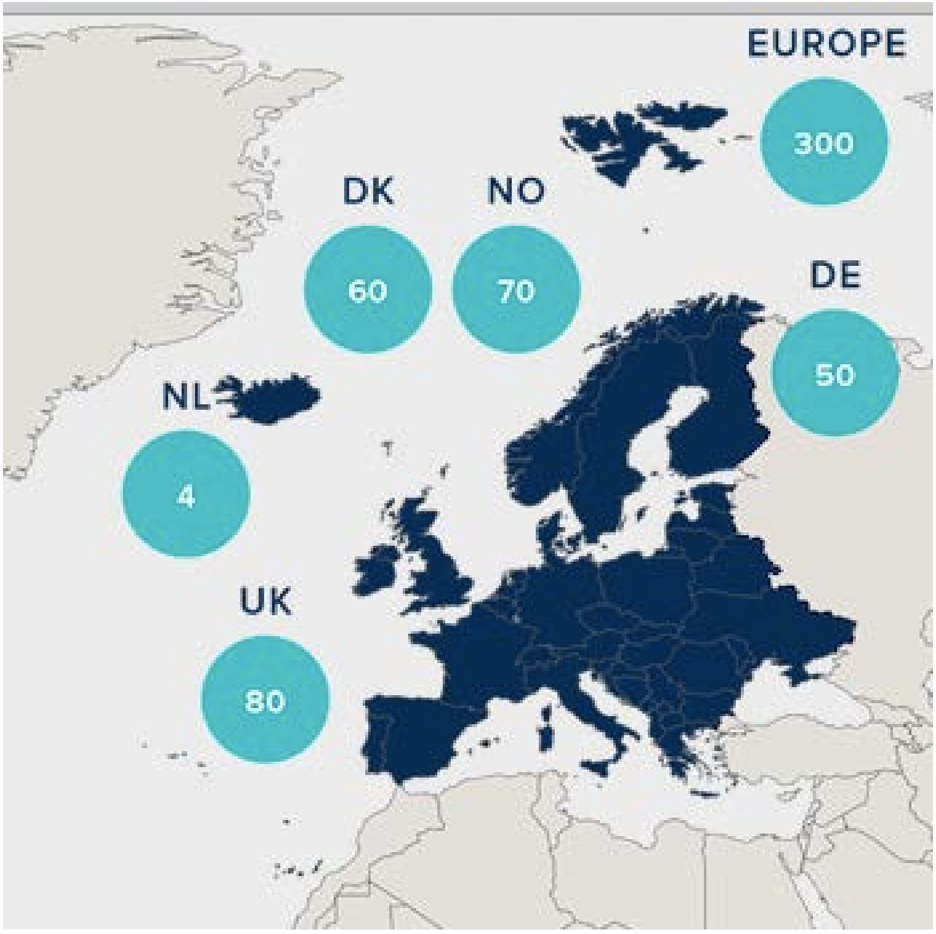

Figure 1 Global CCS Institute map showing the storage capacity (in gigatonnes of CO_2) for the UK and other European countries

In some cases, North Sea oil and gas pipelines, platforms and wells can be reused to allow for the injection of CO_2 rather than the production of oil and gas (i.e. the directions of flow for CO_2 injection being reversed relative to oil and gas production). Asset reuse can both reduce cost and reduce the carbon footprint of the development of CCS. Asset reuse is currently planned for one of the two CO_2 stores being developed in the UK Case Study.

Whilst the case study starts with decarbonizing the Grangemouth and Teesside industrial clusters, there is potential to store CO_2 from industrial clusters across the whole of the UK and to take CO_2 volumes from multiple countries around the North Sea Basin. This short report provides an update of the estimates of CO_2 that are currently planned to be captured on Teesside itself, and compares them to the volumes presented in the East Coast Study[1] that was issued when the ALIGN-CCUS Project commenced. The evidence presented in this report shows that the early 2020 estimates of total volumes of CO_2 from Teesside to be geologically stored by 2050 are very similar to the volume estimates made in the 2017 East Coast Study, upon which the CO_2 supply profiles compiled for the ALIGN-CCUS UK case study were based[2].

There are different technology routes to both decarbonize existing industry and to stimulate new, low-carbon industry. The mix of technologies planned on Teesside is continuing to evolve, particularly as decisions are made on the business models that are being encouraged in the various energy sectors. The envisaged breakdown between CO_2 volumes produced from: a) the manufacture of hydrogen (for large volumes, the lower cost route being reformation of natural gas) for industrial and domestic heat, transport and dispatchable power; b) the CO_2 volumes captured, post-combustion, from industry; and c) the volumes of CO_2 captured from combustion of biomass for energy, are different in the latest estimate and in the East Coast Study. But put simply, the technology used to arrive at very large volumes of CO_2 for geological storage each year is not of significance for the cost-effective storage assessment.

[1] Clean Air-Clean Industry-Clean Growth, Caledonia Energy and Summit Power project, October 2017

[2] ALIGN-CCUS Project Report Deliverable D5.1.4a

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1 Introduction

At the end of 2019, Net Zero Teesside was launched, and the Hydrogen Vision for Teesside was presented to UK industry and government members of the UK CCUS Advisory Group and made public. Volumes of the CO_2 planned for capture and geological storage are collated and presented in this report.

Many aspects assumed in the East Coast Study[1] discussed at length in the Interim Findings remain unchanged:

> "CCS would commence with the current initiatives being promoted by the TVCA and the Teesside Collective including fertiliser (CF Industries), Chemicals (Lotte) and Hydrogen (BOC). It is also assumed that with the large demand for energy, power generation with CCS will also feature with at least one gas- turbine combined-cycle power plant ("GT-CCPP") installed in the initial phases of the CCS Investments. As a source of additional power generation, BECCS capacity is also envisaged at around 1.2 GW in the later phases. This also builds on Teesside being a potential biomass logistics hub, serving Teesside and sites such as Drax. It also seems logical for Hydrogen to feature at Teesside continuing a long presence of Industrial gas production and building on the project identified by the Teesside Collective at the BOC site."

The large scale of energy intensive industry in the UK means that at a relatively low pressure (20-30 bar) gaseous phase onshore gathering systems can be built to cost effectively collect the CO_2 emissions from multiple industrial sites in an industrial cluster. The combined volumes can feed into a central dehydration system and central further stages of compression. At Teesside the initial Net Zero Teesside Project plans to capture 6 million tonnes (Mt) CO_2 per year, with compression to 103 bar, before entering the offshore transportation pipeline. In later years, it is planned to the increase the pressure to 130 bar to accommodate growing volumes of CO_2.. The increased volume to some 10 Mt per year, through the same pipeline, significantly reduces the cost of CCS per tonne of CO_2 stored.

Work is currently ongoing at Teesside regarding capital and operating cost comparisons between post-combustion capture of the CO_2 resulting from burning of natural gas for heat and fuel-switching to hydrogen. On a pure cost basis, and current price assumptions, an industry producing more than around 50 kilotonnes (kt) per year CO_2 emissions should use post-combustion CCS; anything smaller can cost effectively fuel switch to clean burning but more costly hydrogen.

In time, further and significant reduction in the cost of industrial CCS can be envisaged through standard designs for example, of amine plants.

The early 2020 assumptions are given in the next section, in which three scenarios of varying CO_2 capture rate are described for Teesside: Base Case; High Case; Low Case.

2 Teesside CCS Scenarios: 2020 Update

The Net Zero Teesside project, which includes power generation and post-combustion, was updated at the end of 2019 and presented to the CCS Advisory Group (CAG). These figures, with minor early 2020 updates, form the basis for the Teesside Base Case. Bio Energy with CCS (BECCS) in this forecast uses the specific company discussions of the Net Zero Teesside Project as at early 2020. The sources used for input into these scenarios and the assumptions made are outlined in this section.

In addition to these volumes, the growth rate and magnitude of the hydrogen vision for Teesside was also updated at the end of 2019. The largest volumes of CO_2 from the production of hydrogen are from the reformation of natural gas to produce the highly seasonal demand for hydrogen for domestic heating. In line with updates as part of the H21 North of England[3] work by Equinor, three 1.35 Giga Watt (GW) Auto Thermal Reformers (ATRs) are planned to be built on Teesside, half of the six ATRs planned by the H21 North of England Project based at Teesside.

The carbon capture rate and conversion rates are 95% when running in steady state, as per the Net Zero Teesside and the H21 North of England study work. As the percentage collected is higher than the 90% assumed for Steam Methane Reformers (SMRs) in the earlier East Coast Study[1], this increases the CO_2 volumes for storage slightly.

The second largest volumes of CO_2 from hydrogen production are from natural gas reformation for Energy Intensive Industries (EIIs) to switch fuel from natural gas to hydrogen. Since 2017, there has been global experience with fuel switching to clean burning hydrogen to provide heat for EIIs. An assumption has been made as part of the Teesside project forecasting, that all those industrial producers on the Emissions Trading Scheme (ETS) register who are outside a process cluster will eventually fuel switch to hydrogen. The volumes of CO_2 produced from reforming natural gas to make hydrogen for fuel switching are assumed to replace some of the previous post-combustion CO_2 volumes.

Hydrogen for Direct Reduced Iron (Steel DRI) on Teesside is included as per 2019 plans.

Hydrogen for transport (trains, buses, trucks, and cars) has been assumed for Teesside at a modest 10% of recent UK vehicle forecasts with Fuel Cells and Hydrogen Joint Undertaking (FCHJU) hydrogen consumption figures for vehicle types and KPMG figures for vehicle deployment by 2040 (Study for TVCA). It may be noted that hydrogen as a clean-burning fuel for multiple types of ship transport has not been assumed in these figures to 2050.

There is also no shipping of CO_2 for storage in the updated base case forecast i.e. all CO_2 produced on Teesside is assumed to be piped offshore for geological storage below UK waters.

2.1 High Case Teesside Scenario Assumptions

A High Case scenario was prepared with the following increases in CO_2 capture volume by 2050:

i) The rate of growth in BECCS envisaged by the Climate Change Committee for the UK to meet the 2019 Climate Act Net Zero target is significantly larger at Teesside than the base case CO_2 capture? volumes of 2 Mt per year. The high case takes the previous East Coast[1] assumption (Table 3-3) of 10 Mt at Teesside by 2050.

ii) There are no CO_2 volumes from Direct Air Capture and Storage (DACS) on Teesside in the Base Case. An assumption of one at-scale biomass plant capturing 2 Mt per year by 2040 and 4 Mt per year by 2050 is made for the High Case.

iii) Moving to a hydrogen economy for transport may be more rapid than in the Base Case and see a larger proportion of hydrogen generated on Teesside than the 10% in the TVCA analysis in 2020.

[3] H21 North of England Project

However, at 4% of total hydrogen volumes in the forecast, the impact on a High Case scenario is modest and not included. No change is made in the assumption for steel in the High Case.

iv) Assumptions around the ‘roll-out’ rate of hydrogen for domestic heating have a major impact. Each additional ATR in the Equinor work[3] produces 3 Mt per year CO_2 for storage. A slightly faster roll-out rate with two reformers already installed by 2035 is assumed in the High Case, increasing to four reformers on Teesside by 2050 (Base Case has three).

v) In line with the East Coast Study[1], an assumption is made for the High Case scenario on the volumes of CO_2 transported by ship or pipeline from other North Sea Basin countries for geological CO_2 storage below UK waters. This is for 5 Mt per year, commencing in 2035 i.e. only after 10 years of experience with the stores used by Net Zero Teesside. This is a conservative assumption.

It may be noted that the CO_2 volume scenarios for Teesside are not so much decisions about a particular industrial cluster; they depend on policy implementation and decisions on the ‘roll-out’ rate of BECCS and DACS, together with decisions on the hydrogen economy, especially for domestic and industrial heating. They depend also on whether and when in the future the robust technology of reformation of natural gas to produce vast volumes of clean-burning hydrogen becomes no longer obviously cheaper than from other production methods. The scenarios are also dependant on the uptake of commercial arrangements, for example on whether other countries decide to store CO_2 volumes within the prime and abundant geology in the UK offshore region.

The proportion of the increased volumes of CO_2 that are actually produced on Teesside, compared to being produced at another industrial cluster, is not of particular significance for the storage assessment. The UK has geological storage resources offshore the west coast and east coast. The most cost-effective decarbonisation of North Sea Basin countries (plus Island of Ireland) will come from the UK coasts being connected by an onshore CO_2 network. Having multiple North Sea Basin stores linked by shipping and pipeline connections will significantly reduce storage costs and risks for all countries involved. The costs of storage in UK sites will be lower, relative to operation in deeper water, owing to shallower UK water depths, and also due to the shallower subsurface depths of many suitable UK CO_2 stores.

Making use of inland waterways for CO_2 shipping and/or repurposing onshore natural gas pipelines can further reduce CO_2 emissions and reduce costs for North Sea Basin Countries (plus Island of Ireland). Inland networks will allow CO_2 that is captured from energy intensive industry and transport hubs away from the coastal industrial clusters to be collected and stored cost-effectively.

2.2 Low Case Teesside Scenario Assumptions

The small number of industrial emitters included in the initial definition of the Net Zero Teesside Project, as defined at the launch in February 2020, together with the Clean Gas Project[4], is the foundation of a low CO_2 volume case. The Clean Gas Project CO_2 capture ambition is 1.36 Mt per year lower than the Teesside Net Zero Base Case.

Lower and slower assumptions on the transfer from a fossil fuel- to a hydrogen-based economy, especially for domestic heat, were made for the Low Case. A 5-year delay in operation of the first ATR, and a slower increase to a total of only two ATRs on Teesside is assumed, in contrast to three ATRs in the Base Case as specified in the Equinor H21 North of England study[3].

CCS is assumed in the Low Case to come into operation too late for many of the smaller energy intensive industries. Slower and smaller uptake of fuel switching to hydrogen from the smaller companies (below 50 kilotonnes (kt) per year) is assumed in the Low Case. Projects not previously defined in Net Zero Teesside are assumed not join the scheme later.

Steel DRI in the Low Case is not assumed to expand beyond the first phase.

[4] The Clean Gas Project is a CCUS project based at Teesside

3 Volumes of CO_2 from Teesside for Storage: 2020 Update

The Teesside projected CO_2 volumes are presented in the summary tables below, as total volumes. The split is also shown in the tables between CO_2 from industry and power generation, the CO_2 produced from the production of hydrogen using Auto Thermal Reformation and, in the high case, CO_2 imports. It is of interest to note that the total base case 2050 volumes are similar (20 Mt per year) to the work of the 2017 East Coast Study (21 Mt per year) as reported in the ALIGN CCUS Deliverable[2].

The proportion of these volumes coming from the various technologies used to decarbonize has evolved over time, but the size of the challenge and the opportunities of job retention, job creation, cleaner air and value for money decarbonization remain in place.

*Table 3.1: Total captured volumes of CO_2 for storage from Teesside **in kilotonnes (kt)**, early 2020 planning, Base Case*

CO_2 Source	Description	2025	2030	2035	2040	2045	2050
Teesside Industry & Power	Includes collecting CO_2 from existing H_2 production	1800	5200	6561	6561	6561	6561
Teesside new H_2 production	Includes 3 x 1.35 GW reformers of H21 North of England Project	443	4621	5100	9330	12981	13590
Total CO_2 volumes	**per year for storage**	**2243**	**9821**	**11660**	**15891**	**19542**	**20151**

*Table 3.2: Total captured volumes of CO_2 for storage from Teesside **in kilotonnes (kt)**, early 2020 planning, High Case*

CO_2 Source	Description	2025	2030	2035	2040	2045	2050
Teesside Industry & Power	Includes collecting CO_2 from existing H_2 production	1800	5200	10084	14084	16084	20084
Teesside new H_2 production	Includes faster 4 x 1.35 GW reformers	443	4621	8143	9330	12981	16633
CO_2 Imports		0	0	5000	5000	5000	5000
Total CO_2 volumes	**per year for storage**	**2243**	**9821**	**23227**	**28414**	**34065**	**41717**

*Table 3.3: Total captured volumes of CO_2 for storage from Teesside **in kilotonnes (kt),** early 2020 planning, Low Case*

CO_2 Source	Description	2025	2030	2035	2040	2045	2050
Teesside Industry & Power	Includes collecting CO_2 from existing H_2 production	1800	5200	5200	5200	5200	5200
Teesside new H_2 production	Includes slower introduction of 2 x 1.35 GW ATR reformers	0	1143	4665	5191	8843	9017
Total CO_2 volumes	**per year for storage**	**1800**	**6343**	**9865**	**10391**	**14043**	**14217**