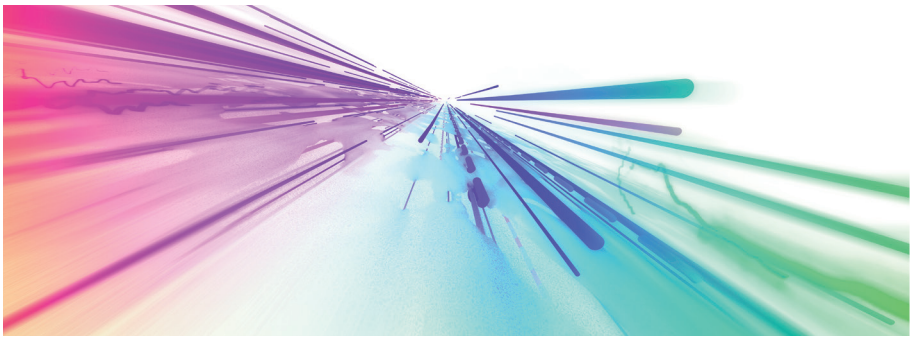
CARBON CAPTURE AND STORAGE

and the opportunity for the oil and gas supply chain

OEUK Special Report

NORTH SEA *Transition Deal*

July 2022




H2
Hydrogen H2
zero emission

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1. Foreword

Welcome to the first in a series of OEUK reports examining how the UK's offshore oil and gas supply chain will drive the country's transition to cleaner energies. This focuses on how supply chain companies can capture the lion's share of the future carbon capture and storage (CCS) industry. CCS will be a vital tool in helping to meet the commitments of the Paris Agreement.

As one of the first industrial sectors to come out in support of the UK government's 2050 net zero target, we consider CCS a matter of national interest to our economy and our environment. However, as the report shows, without urgent and focused action, the UK will miss out on vital CCS investment; the opportunities for jobs and communities in industrial heartlands; and any hope of establishing a leadership position for the UK in this exciting new sector.

But with CCS, UK can maintain reliable supplies of energy, cut emissions, generate jobs and create huge export opportunities. This report is therefore timely in setting out the dozen or so actions that governments and industry can take to ensure our supply chain benefits from these opportunities.

Offshore Scotland, east England and Merseyside lie rock formations with the potential to hold up to 78 billion tonnes of Carbon Dioxide (CO_2). That is the equivalent of two centuries' worth of the UK's emissions today.

The prize is therefore huge: our report finds CCS could be worth around £100bn to the offshore oil and gas energy supply chain by 2050 and £20bn in this decade alone.

The UK is well placed to become a world leader in this game-changing technology. Last year, the government and industry made CCS a key element of the North Sea Transition Deal. The government's Net Zero Strategy says carbon capture capacity could exceed 20mn metric tons/yr of CO2 by the early 2030s – more than double the Ten Point Plan – and at least 50mn metric tons/yr by the mid-2030s.

As this report demonstrates, the UK has three of the four components necessary to make CCS a great success – including a potentially significant market for exports of technology and expertise. We have large industrial clusters emitting CO_2; extensive gas transport infrastructure that may be repurposed; and a good scientific understanding of the geological requirements for long-term CO_2 storage.

However, the fourth component, our supply chain, is fragile. Its margins are low and over the years, heavy manufacturing has lost out to competition from overseas. The UK is at risk of losing this world-class supply chain as investors follow more attractive opportunities elsewhere.

We need to act fast on this and we know that if 100 CCS storage sites are needed to reach net zero by 2050, the planning process must start in short order.

To do this, supply companies need confidence. As our report finds, the way we do business has to change, with CCS licensees engaging early with their supply chain. Open communication and collaboration will allow companies to see what's over the horizon and plan accordingly.

Government needs to approve projects rapidly so that clear strategic commitment can be given to provide companies with the confidence to

build the transport and storage needed to make CCS a success in the UK.

This year, the North Sea Transition Authority launched the first licensing round offering 13 areas suitable for carbon capture projects off our coasts.

And in 2021, the UK government selected the first carbon capture cluster projects to be fast-tracked for deployment by the mid 2020's. These are the Hynet cluster, based in northwest England and North Wales, and the East Coast cluster, made up of Zerocarbon Humber and Net Zero Teesside. Already, 41 energy-intensive companies are now in talks with potential CCS operators to understand how CCS can support them as they transition their businesses.

All of this serves to demonstrate that good progress is being made. But a lot more work is to be done if these schemes are to become reality.

Above and beyond a strategic commitment to making CCS happen for UK companies, governments need to ensure confidence in the UK's potential for clean energy. Supporting a stable regulatory and fiscal framework continues to be key to this and despite the continuing economic and political turbulence, governments need to demonstrate their ongoing commitment to delivering net zero by 2050, while recognising the role of domestic oil and gas production during this journey.

The UK oil and gas energy supply chain is key to underpinning the energy transition through the development of CCS, and hydrogen and offshore wind will present further opportunities for the UK to decarbonise while continuing to foster economic growth.

This is why, following this report, OEUK will be publishing one on offshore wind and then hydrogen, followed by a ground-breaking supply chain roadmap that will combine all these insights to provide a pathway forward.

OEUK is delighted to create and promote these insights as blueprints for the UK's changing offshore oil and gas energy supply chain – blueprints that must now be acted upon.

Katy Heidenreich

Supply Chain & Operations Director
Offshore Energies UK

2. Executive Summary

The UK is on the way to becoming a global leader in carbon capture and storage (CCS)[1] thanks to an ambitious policy framework, clear support mechanisms and its existing supply chain capability. With the development of Track 1 clusters now moving forward, key high-value investment opportunities will come to market and be contracted in the next 24 months. We are at a critical point in ensuring that the UK supply chain can respond competitively and so secure UK supply chain content. If we get this right, the UK offshore oil and gas industry supply chain will be well placed to not only capture the lion's share of government-supported projects, but also international opportunities as well.

This report, prepared with support from EY, considers the readiness of this supply chain to benefit, supporting investment and jobs in communities around the country. It forms part of OEUK's work in relation to the North Sea Transition Deal (the Deal), and aims to provide actionable insight for policy-makers and the UK supply chain leading to successful project delivery and reaching the national content targets for CCS projects.

Subsequent reports will assess the potential of offshore electrification and floating offshore wind and hydrogen[1].

Key findings of this report

The offshore oil and gas industry is agile

The UK oil and gas supply chain has technological experience that will be invaluable in CCS, and its highly skilled workforce is well used to navigating the choppy waters of oil and gas price volatility. There is a clear determination that CCS should be part of a diversified energy transition portfolio and there is genuine excitement at the opportunity.

Bottlenecks are likely in major areas of the CCS supply chain

CCS investments are part of a major programme of energy and infrastructure in the UK, competing for key skills and materials. In particular, the construction and commissioning sector will need to respond to demand coming simultaneously from nuclear, hydrogen, and other renewable energy sectors as well as non-energy-related infrastructure.

Support is needed for UK competitiveness

The UK is not a competitive manufacturer of a significant proportion of the technology that will need capita investment. In particular, labour costs and productivity challenges could threaten major plant fabrication. Intervention is required if the UK is to capitalise on the high-value elements of CCS opportunities.

Invest to gain early-mover advantage

Investment is required to support CCS-specific requirements and demand volume for major plant fabrication. Construction requires investment in highly skilled labour to avoid delays or relying on imports.

[1] Carbon capture & storage (CCS) is also referred to as carbon capture, use & storage (CCUS). This report does not deal with the use of CO_2, hence the reference to CCS throughout this report.

Scale of the opportunity

Achieving the UK's CCS ambitions could cost up to £20bn[2] over the next ten years and around £100bn by 2050. Given that investment in conventional fossil fuel projects is expected to decline, this is a sizeable opportunity for the supply chain. The split of capital investment across capture, transport and storage depends on many projects or cluster-specific factors, such as the number and type of capture projects, the pipeline length, potential re-use of existing assets, and so on. The table below provides an indicative range of capital investment split, drawn from published analysis[3] and stakeholder insights.

The report uses this indicative split to quantify the scale of opportunities and hence the priority for action. While all areas need a significant level of investment, the analysis shows that UK capability is not the same in each area and hence industry and policy makers have different actions to consider. Operating costs (Opex) have also been considered in the body of the report.

	Carbon capture				Transport & storage	
	Design and engineering	Major plant fabrication	Equipment design & manufacture	Construction & commissioning	Pipework supply and installation	Storage – wells, subsurface and reservoir
Proportion of Capex	10%- 15%	15%- 25%	15%- 20%	25%-35%	10% - 15%	5% - 10%
Est. share of £20bn investment (£bn)	2.0-3.0	3.0-5.0	3.0-4.0	5.0-7.0	2.0-3.0	1.0-2.0

[2] Capital investment estimated based on available sources and stakeholder insight

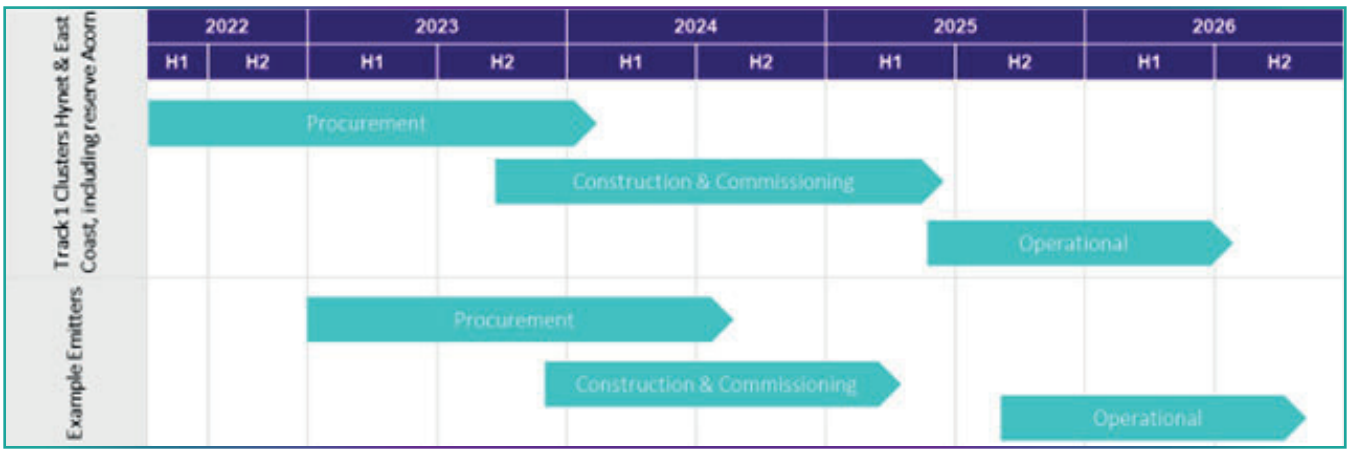
[3] 1. https://www.rystadenergy.com/newsevents/news/press-releases/carbon-capture-and-storage-service-spending-to-total-more-than-$50-billion-globally-by-2025/?utm_campaign=&utm_content=&utm_medium=&utm_source=linkedin
2. https://ukerc.rl.ac.uk/ETI/PUBLICATIONS/AdHoc_CCS_CC1025_3.pdf
3. https://www.globalccsinstitute.com/archive/hub/publications/17011/costs-co2-capture-transport-and-storage.pdf

[4] https://www.gov.uk/government/publications/the-ten-point-plan-for-a-green-industrial-revolution

Timeline of CCS deployment

The UK government, in line with its Ten Point Plan[4], launched a process in May 2021 to identify and sequence CCS projects suitable for deployment in the mid-2020s. It also committed £1bn to a CCS Infrastructure Fund (CIF). CIF support will come in two phases: Track 1 clusters will lay the foundations and infrastructure for a CCS transport and storage network while Phase 2 capture projects will be able to connect to the transport and storage infrastructure network that the Track 1 clusters have set up.

The indicative timeline below shows activities across the transport and storage elements of the Track 1 clusters: HyNet North West and the East Coast Cluster. Track 1 clusters have recently begun the market engagement process for transport and storage, to understand specific supply chain capabilities needed for their project requirements. The reserve Acorn project is also engaging with the market. The timeline below shows what emitter projects are likely to need. There is little time to ramp up capacity to meet the future demand for Track 1 clusters. It shows that 2023 – 2025 is a critical period if the supply chain is to take advantage of the fabrication, manufacturing, construction and commissioning opportunities.



Key findings by supply chain area [Capex]

Below are the key findings from interviews, surveys and desktop research in the major areas of the emerging CCS supply chain. These are expanded upon later in the report.

Supply chain activity		UK capability	Value and accessibility of opportunity	Key finding and action required
Capture	Plant design & engineering			**Key findings:** • The UK supply chain is strong and is already delivering pre-front end engineering (FEED) design (Pre-Feed) and Feed for UK CCS projects. **What is needed:** • Clarity and commitment from government to future expansion of CCS and ongoing funding for early stages of future clusters and projects.
	Major plant fabrication			**Key findings:** • UK capabilities have declined in major plant fabrication and some CCS requirements are highly specified across different emitter projects. • There are barriers to UK competitiveness from labour costs, productivity challenges and the ability to produce the largest fabricated components at home. • There may be specific opportunities for major plant fabricators, including mini-modules and specialised pressure vessels. • Some companies say more production facilities are needed to meet CCS technical requirements and future demand growth. **What is needed:** • Industry to develop clear visibility to enable planning and expansions in capacity. • Government to evaluate the case for targeted support for investment in UK fabrication capacity, connecting this to developer incentives to use the UK supply chain. The offshore wind sector shows how the supply chain might adapt to CCS[5]. • Government to assess ways of making the UK competitive such as the introduction of a carbon border adjustment mechanism or carbon product standards. • Industry is encouraged to consider standardising the fabrication of plant. Modular components can cut production costs.

Capture	Equipment design & manufacture			**Key Findings:** • Most components are suitable for global markets being relatively tradeable and used in many sectors. • There is limited opportunity for the UK supply chain to step up where it is not already active, but there may be an opportunity in niche future requirements. **What is needed:** • Government to consider measures to attract investment from international businesses to increase capacity. • Government and industry to pursue niche research and development opportunities identified in Technology Gap Assessment through the Technology Leadership Board.
	Construction & commis-sioning			**Key Findings:** • This is a major opportunity: existing UK capability is adequate and it can make a major contribution to local content ambitions. • A major gap in resources might open up in this area with high demand for labour and materials in the next 10 years as nuclear, hydrogen and other sectors compete with CCS. **What is needed:** • Continuing action by industry under the "people and skills" strand of the Deal.

[5] See Introduction section of this report for the Offshore Wind supply chain Plans case study

Supply chain activity		UK capability	Value and accessibility of opportunity	Key finding and action required
Transport	Pipework onshore & offshore supply & installation			**Key findings:** • The UK can install plant on and offshore but it lacks a competitive capability for the supply and fabrication of the pipework to the right specification. • The UK manufacturing sector has limited capability and Track 1 CCS projects will probably need to source equipment from overseas. **What is needed:** • Government to assess means to support UK competitiveness with international competitors. This may include a carbon border adjustment mechanism or carbon product standards.
	Marine transport of CO_2			**Key findings:** • This is a new industry and there is no UK activity to date. • There will be UK requirements (memorandums of understanding in place between clusters), but a major driver could be CO_2 from abroad. • While it is recognised as an opportunity, it would take a significant and nationwide effort to capture the opportunity from shipping. **What is needed:** • Government to quantify the opportunity and develop a business case under the shipbuilding strategy.
	Marine loading & offloading			**Key findings:** • The major driver would be importing CO_2 from other European regions by ship, to use UK storage capacity. **What is needed:** • Government to assess the capacity of existing UK port infrastructure to offload CO_2 shipments.

Storage	Wells, subsurface & reservoir design & engineering Marine & subsea contractors			**Key findings:** • The UK has strong storage development capability through the oil and gas supply chain. • Companies are already providing well, subsurface and reservoir engineering services to the early clusters. • For marine and subsea contractors, key scope elements depend on access to globally optimised equipment and services which are common to other energy developments. **What is needed:** • Industry regulators to develop clear visibility of further storage development and a progressive approach to avoid bottlenecks on rigs etc. • Industry guidance on the operation of rigs in a CO_2 environment.

Key to icons

	Scale definition	
	Capability	**Value & accessibility of opportunity**
	The UK can supply all the required capability.	There is a significant opportunity, readily accessible to the existing supply chain.
	The UK can supply most of the required capability.	There is a significant opportunity but some constraints or barriers to access.
	The UK has moderate coverage of the required capability.	There is a moderate opportunity with constraints or barriers to access.
	The UK has limited coverage of the required capability.	There is a limited opportunity with challenging constraints or barriers to access.
	The UK has minimal coverage of the required capability.	There are prohibitive constraints of access limiting the value of the opportunity.

The report also includes operating expenses at all stages from carbon capture to reservoir monitoring. These can be found in Sections 5.1 and 6.6.

The above assessment was based initially on desktop analysis while stakeholder interviews provided the insight to determine the capability of levels 1-2 of the CCS taxonomy (see Appendix B). A select number of level 3 areas were selected to conduct 'deep dives' to provide primary data to support or challenge findings in the main body of this report and these are included as Appendices.

3. Introduction and methodology

3.1 Background: the UK approach to CCS

Carbon capture and storage is "a necessity, not an option" for the UK's ambition to transition to net zero by 2050.[6]

The adoption of a net zero target for the UK economy under the Climate Change Act relaunched efforts to establish a carbon capture and storage industry in the UK. In 2021 the government launched a Net Zero Strategy that set out the goal of capturing and storing 20mn – 30mn metric tons (mt)/yr of CO_2 by 2030 via four CCS clusters. The government has committed to a £1bn Carbon Capture and Storage Infrastructure Fund (CIF) to support these developments. The government's objective has since been extended to 50 $MtCO_2$ by the mid-2030s[7].

3.2 The North Sea Transition Deal

The Deal was the first of its kind by any G7 country and will accelerate the energy transition, reduce UK emissions, and create new jobs across the UK. The Deal recognises the industry's role in providing secure supplies of energy, meeting the governments net zero ambitions while also developing skills which can be exported globally. The commitment made by the oil and gas sector to contribute to the CCS objective was a key element of the Deal.

In November 2021 OEUK was commissioned to execute the Supply Chain Transformation element of the Deal (further details can be found in Appendix F) and this report forms part of OEUK's work in relation to this. While the Deal's full scope also includes electrification, floating offshore wind, and hydrogen, this report is focused on one decarbonisation technology - namely CCS. Similar reports for offshore wind and hydrogen will follow.

CCS progress timeline

April 2019
Government commits to deliver a transformational sector deal for offshore oil and gas sector.

March 2020
The Carbon Capture and Storage Infrastructure Fund (CIF) is announced in the Budget in March 2020, with an allocation of £1bn.

November 2020
CCS is the eighth point of the Ten Point Plan. The Plan originally listed an ambition of 10mn mt of CO2/yr by 2030. But this was revised, and the target now stands at 20-30mn mt/year. Furthermore, there was a commitment to deploy CCUS in a minimum of two clusters by the mid-2020s and four clusters by 2030 at the latest.

March / April 2021
The Deal builds on the UK's global strength in offshore oil and gas production and seeks to maximise the advantages for the UK's oil and gas sector from the global shift to clean growth key outcomes, with supply chain Transformation being the element this report is built on.

October 2021
The HyNet and East Coast Clusters are confirmed as the Track 1 Clusters for the mid-2020s and will be taken forward into Track 1 negotiations. Additionally, the Scottish Cluster (Acorn) will be in reserve.

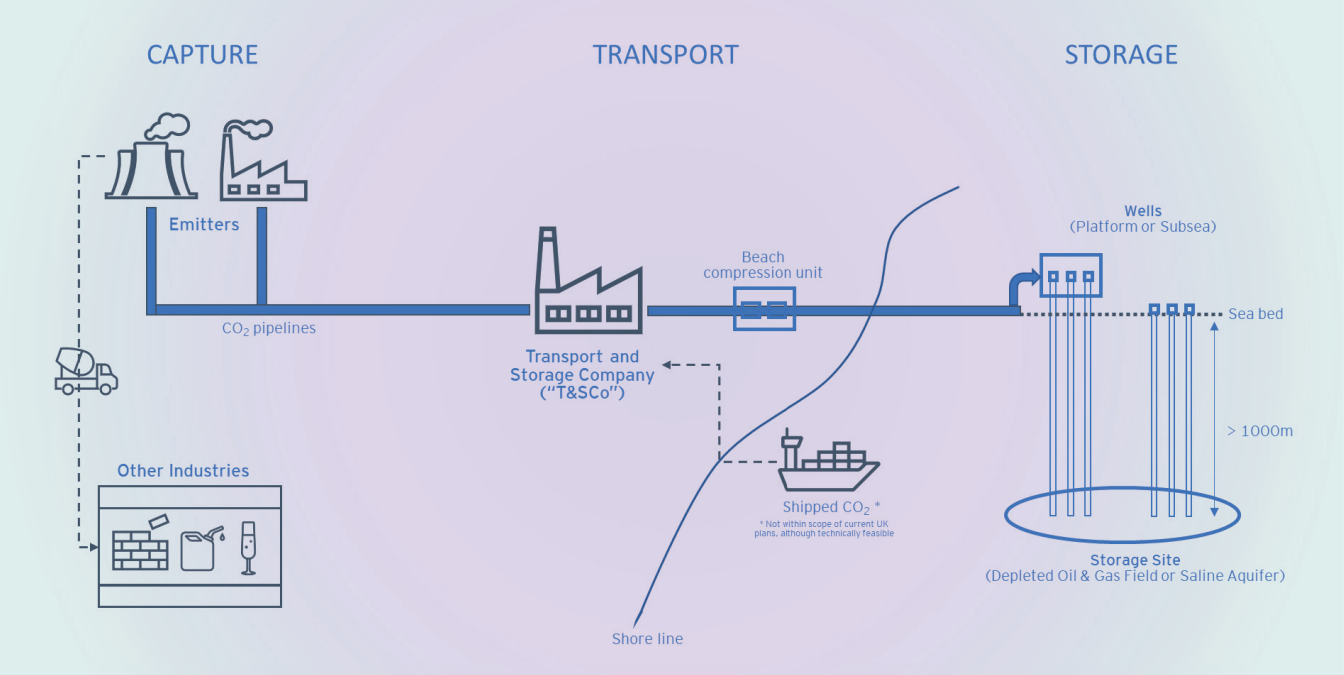
November 2021
OEUK tasked with executing the supply chain Transformation element of the NSTD.

March 2022
As many as 41 power generation, industrial & hydrogen + CCS projects were announced as eligible to proceed to the Phase 2 cluster sequencing process.

[6] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1068444/ccus-roadmap.pdf

[7] CCUS Delivery Plan 2035, https://www.ccsassociation.org/wp-content/uploads/2022/03/CCSA-CCUS-Delivery-Plan-2035-MASTER-Final.pdf

Illustrative overview of carbon capture, transport and storage.



3.3 Carbon Capture & Storage: UK potential

The UK is surrounded by geological formations and depleted oil and gas reservoirs that have excellent characteristics for a successful and long-term CCS industry. The British Geological Survey, in partnership with the Crown Estate, has identified over 78 gigatons of CO_2 storage capacity under the UK seabed. This is enough to support the UK's demands for centuries, with the bulk located in the North Sea. There is also an opportunity to store other countries' carbon emissions.

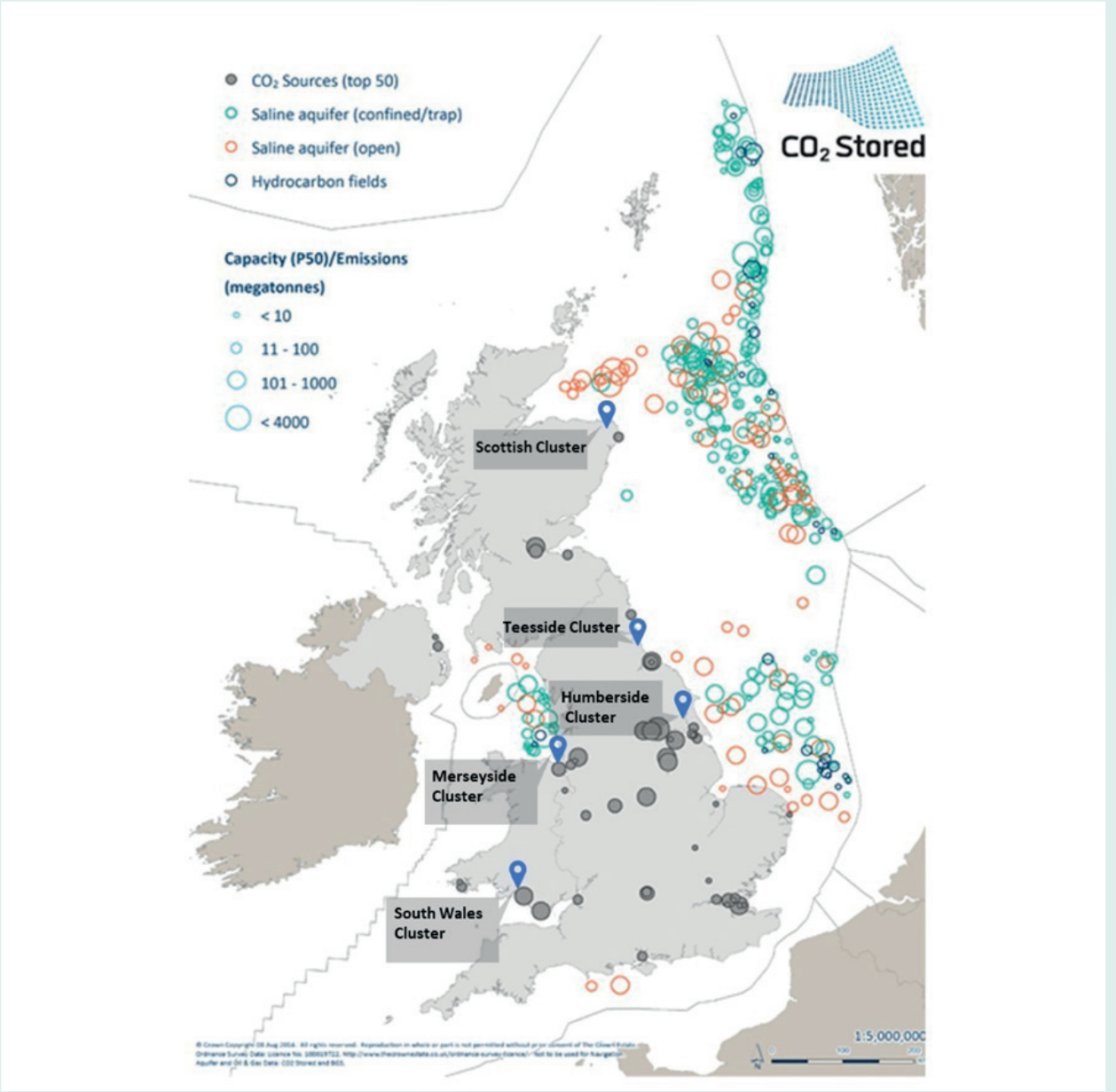
Business model development is underway for CO_2 transport & storage (T&S) infrastructure; power generation + CCS; industry + CCS; low carbon hydrogen production & infrastructure; and bio-energy developments. Alongside this, in May 2021 the government began the cluster sequencing programme. To qualify for the process, each cluster needed to credibly demonstrate it could be operational by 2030 and meet the definition of a cluster: i.e. a T&S network and at least two capture projects.

The government recently announced its Track 1 clusters, which will be the first to receive CCS infrastructure funding, and qualify for bi-lateral business model engagement, naming the East Coast Cluster, which is a combined bid from Net Zero Teesside and Zero Carbon Humber, and HyNet, containing businesses across the northwest & Merseyside as Track 1 with Acorn, the Scottish Cluster based in Aberdeenshire, in reserve. These three clusters alone will provide the UK with 37mn mt/yr of CO_2 storage capability by 2030. The DelpHYnus and V Net Zero clusters in the East of England were deemed to meet eligibility criteria but have not yet been selected for government support. They may apply for Track 2 approval.

Once the Track 1 clusters were selected, power, industrial carbon capture (ICC), and blue hydrogen projects were submitted for CIF support and connection to the transport and storage infrastructure network established by Track 1 or the reserve clusters. As part of

the Phase 2 cluster sequencing process, public notifications in March 2022 stated a total of 41 projects are proceeding to the evaluation stage, signalling a substantial level of interest for industrial emitters to decarbonise through CCS. The total capacity of these projects, plus other clusters provides the UK with the potential to capture 70mn mt CO_2/yr by 2035[8].

This demonstrates the level of activity starting across the clusters: there is a novel opportunity for the UK's supply chain, with intense activity in the rest of this decade.



[8] CCUS Investor Roadmap, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1068444/ccus-roadmap.pdf

Case Study

Offshore wind supply chain plans

The offshore wind sector presents several relevant insights in developing plans for supply chain transformation in the CCS sector.

The government wanted to ensure a lot of the components for the UK offshore wind industry were sourced domestically but it has proved difficult to entice developers (who are incentivised to compete on cost through the CfD subsidy mechanism for renewables) to use UK manufacturing facilities.

The government has undertaken a range of interventions to promote the achievement of this objective:

1. Encouraging the offshore wind developers to collectively agree on a supply chain target of 60% UK content by 2030 within the Deal in exchange for other government commitments.
2. Putting a value on it: committing to a target of 40 GW offshore wind to be deployed by 2035 (since increased) to signal the size of the future UK market.
3. Requiring supply chain development plans as a precondition for CfD support, and then assessing compliance with the plan ahead of final investment decisions as a milestone condition. This pushes developers to submit more realistic supply chain plans ahead of the CfD auction and also to develop earlier partnerships with suppliers so that they know what is deliverable. Encouraging partnerships with the supply chain at the outset gives suppliers confidence in a growing order book if they situate plant in the UK.
4. Targeted government support where supply chain barriers have been identified that cannot easily be addressed at the developer level – for instance by investing £95mn in two offshore wind port hubs on the Humber in Teesside.

Incentives for developers to contract with suppliers have to comply with state subsidy law or risk legal challenges.

The recent ScotWind offshore wind tender was sufficiently dramatic to underpin the investment in the largest turbine tower manufacturing facility in the Scottish Highlands. The facility[9] has received financial backing totalling £15mn in debt from SSE. Mainstream Renewable Power is a key lender in the funding syndicate, providing £5mn in debt, as well as a strategic partner in the long-term development of the facility. Further funding support from the Scottish government is expected via the Highlands and Islands Enterprise body and the UK government via the offshore wind manufacturing investment support scheme.

[9] https://gegroup.com/latest/nigg-offshore-wind-announcement

3.4 Insights from the oil and gas supply chain

The first element of the methodology used in this assessment (see Appendix D) was to carry out initial stakeholder engagement sessions across the value chain. This provided valuable insights were drawn that helped shape the Level 2 opportunity analysis and the deep dives. Below are high-level examples of sentiment towards CCS and its potential within the UK.

Maintain Momentum

'We cannot lose the momentum we have built around CCS'

Public and private investment will continuously be needed to make CCS a success alongside providing trust and security to investors. Due to the cancellation of the Government's previous CCS competition, this trust will be critical for developers and the investment community. Demonstrating a commitment to a UK supply chain is a lever that can be pulled

Collaborative Experience

'Magic happens at the intersection between things, domain expertise from one sector being shared with another'

CCS is new and the partnerships are only beginning to be formed, the Oil & Gas sector has a legacy of collaboration, sharing risk and reward. Through the cluster model we are already seeing this being followed by the CCS sector, a critical next step will be ensuring lessons learnt and cost reduction techniques are shared

Workforce & Skills

'The government should be involved in workforce planning'

'We have an ageing profile of the existing workforce, as well as a degree of feeling disenfranchised with challenge ahead'

Concern has been expressed of the ageing Oil & Gas workforce and a lack of investment towards it to make Net Zero a success. This poses a threat that future talent is not exposed to the collective experience and knowledge of the current workforce and how it can be applied to CCS & other sectors

The following sections will look to explore more specific areas of the CCS supply chain, split across capture, transportation and storage, allowing a more focused look at each core element of the sectors and the opportunities within. This includes references to deep dive assessment and a survey of businesses in particular sub-elements of the supply chain as set out in the Methodology.

Visionary Outlook

'The UK is creating a first mover advantage in CCS, through policies that cover the full CCS value chain, from Power & Transport & Storage, to Greenhouse Gas removal'

The first mover advantage can be strengthened by securing a robust and competitive supply chain that delivers in the UK, and provides the companies involved with a Global export opportunity to other nations deploying CCS

Agile Policy Development

'The regulator should not underestimate the risk that CCS brings'

'fail fast and scale fast'

'Policy needs to be developed in a cooperative and experimental manner'

Collaboration and a solid public/private partnerships in the adoption of CCS is a critical factor for success, trust is essential and agile policy development needed

Public Perception

'Strong public perception is critical in order for the future of CCS to land successfully with the public'

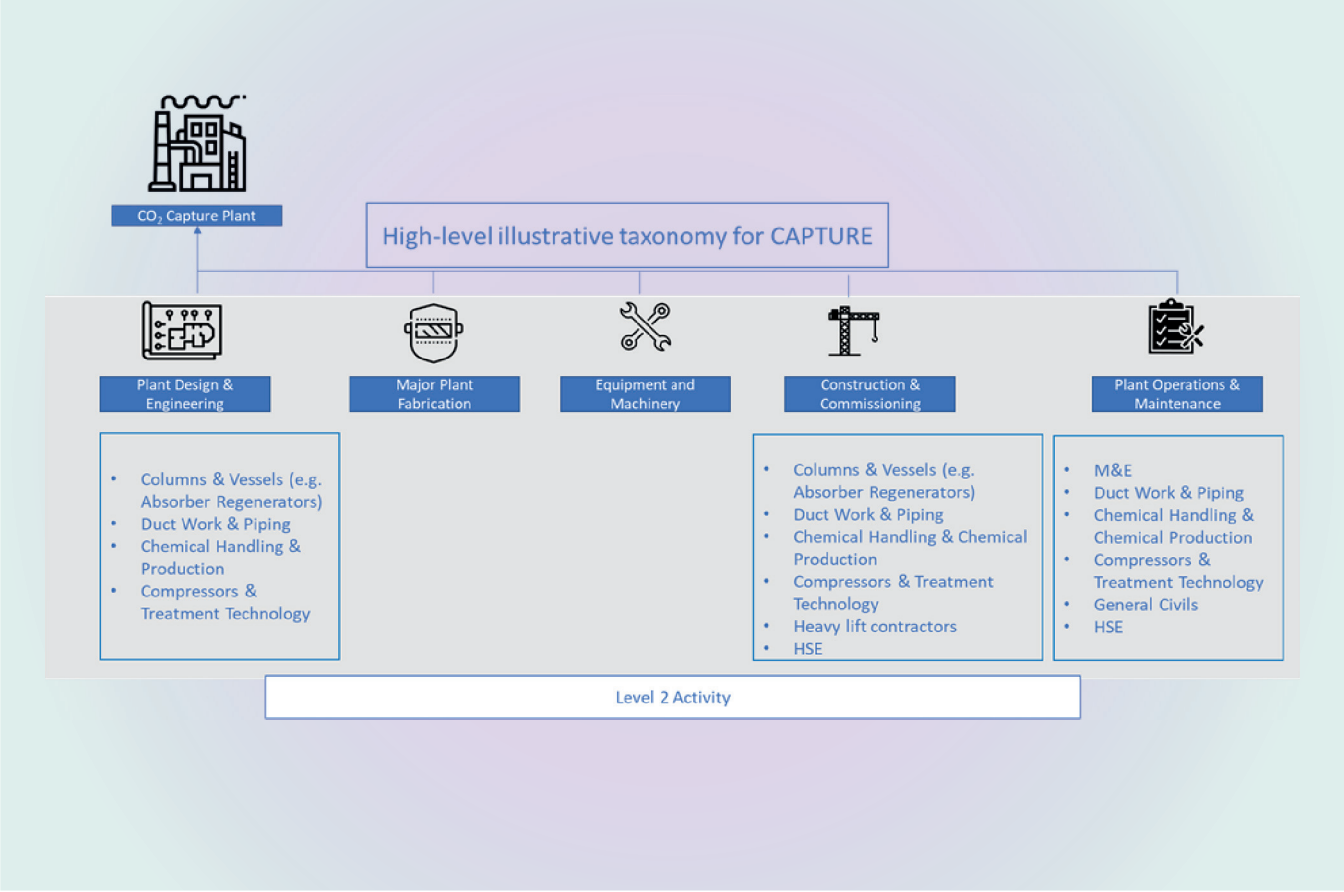
It will be critical for the sector to demonstrate the safety and opportunity CCS brings. This can be done through stringent policy and regulation, and a nimble supply chain that is investing in assets and people

4. Key elements of CCS

The supply chain for CCS falls into a number of logical parts. There is no industry-accepted system, or taxonomy, for how these are classified. The diagrams below describe the method used in this report and are intended to help supply chain companies looking to expand business opportunities. *(See also Appendix B)*

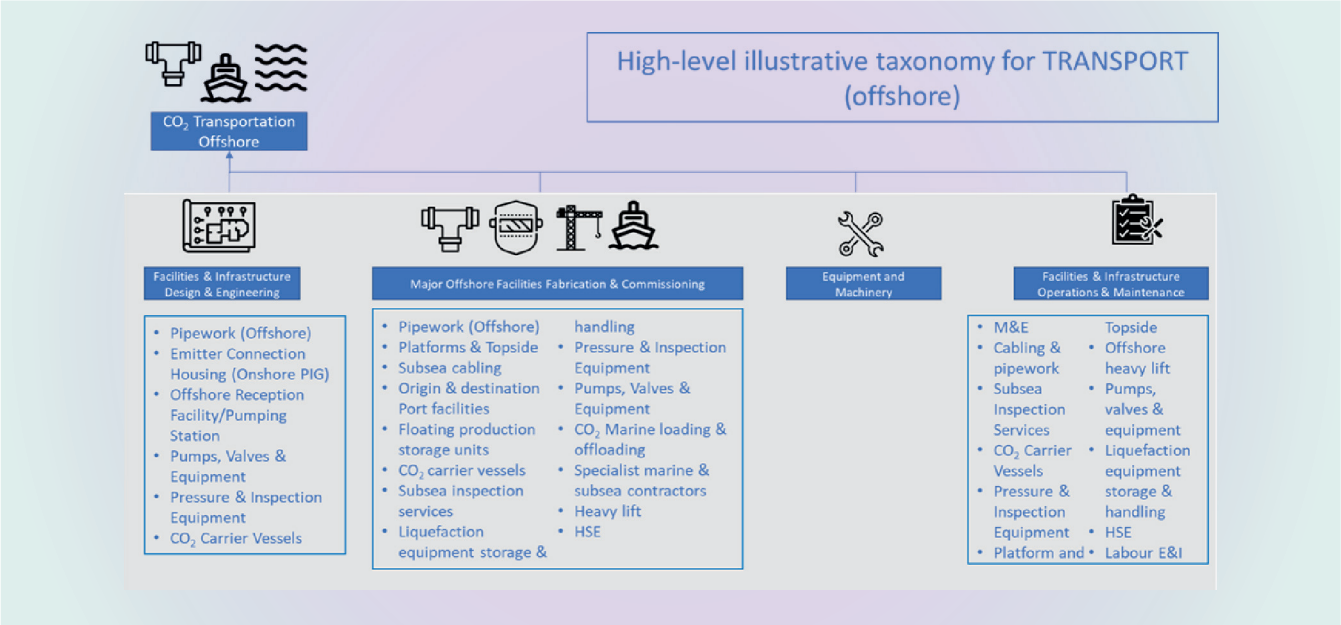
4.1 CO_2 capture

High-level illustrative taxonomy for capture and assessment of Level 2 activity has been detailed in section 5 of this report. Deep Dives were conducted on the fabrication of columns, vessels, ductwork and piping



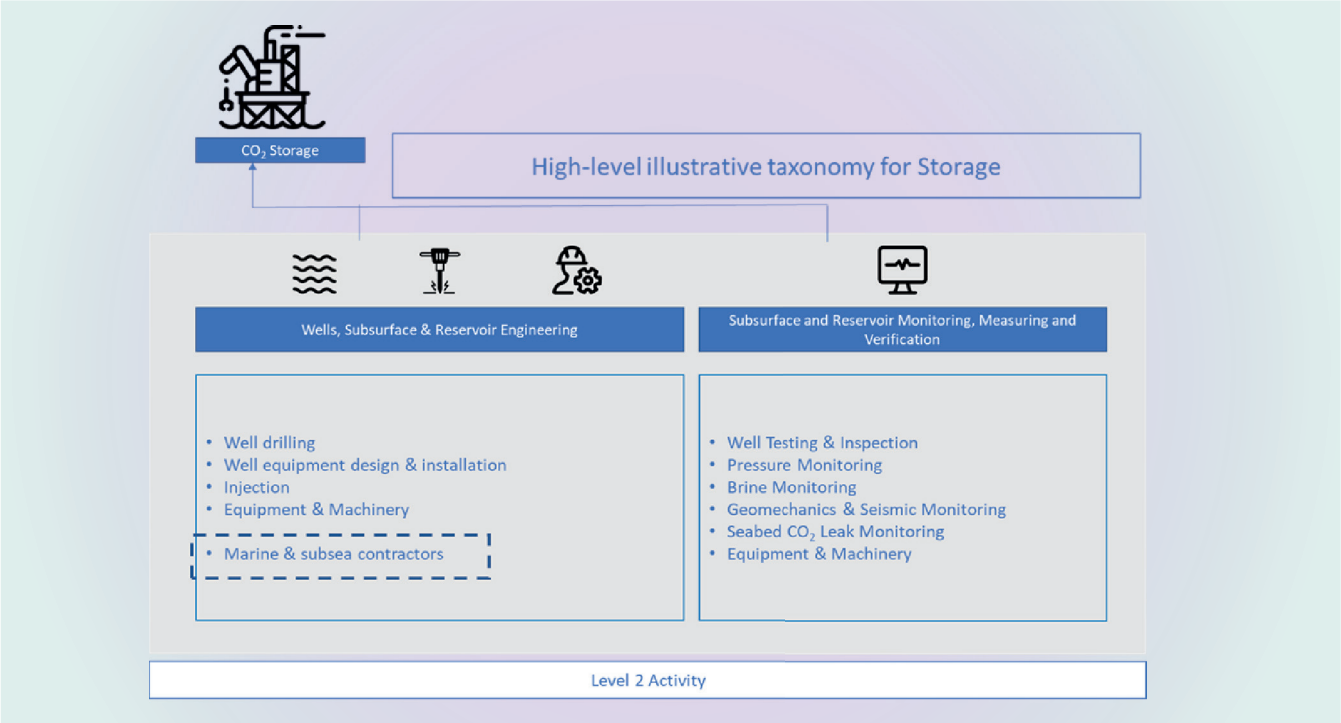
4.2 CO_2 transport

High-level illustrative taxonomy for Transport (onshore). Assessment of Level 2 activity has been detailed in section 6 of this report.



4.3 CO_2 storage

High-level illustrative taxonomy for Transport (offshore), assessment of Level 2 activity has been detailed in section 6 of this report.



There were deep dives into offshore storage development, geomechanics, permeability, MMV & seismic monitoring, and well services & engineering.

4.4 CCS cost breakdown

Data on the capital cost-share of high-level components of CCS projects were examined, but variable operational costs such as energy/ steam production were excluded. It is hard to assign a value to these, owing to the varying applications.

The table below illustrates how an upfront capital expenditure (Capex) opportunity of £20bn might be split between the major supply chain components of the classification described above.

	Capture				Transport & storage	
	Design & engineering	Major plant fabrication	Equipment design & manufacture	Construction & commissioning	Pipework supply & installation	Storage - well, subsurface and reservoir
The proportion of Capex- low	10%	15%	15%	25%	10%	5%
The proportion of Capex – high	15%	25%	20%	35%	15%	10%
Share of £20bn investment (£bn)	2.0-3.0	3.0-5.0	3.0-4.0	5.0-7.0	2.0-3.0	1.0-2.0

5. Capture

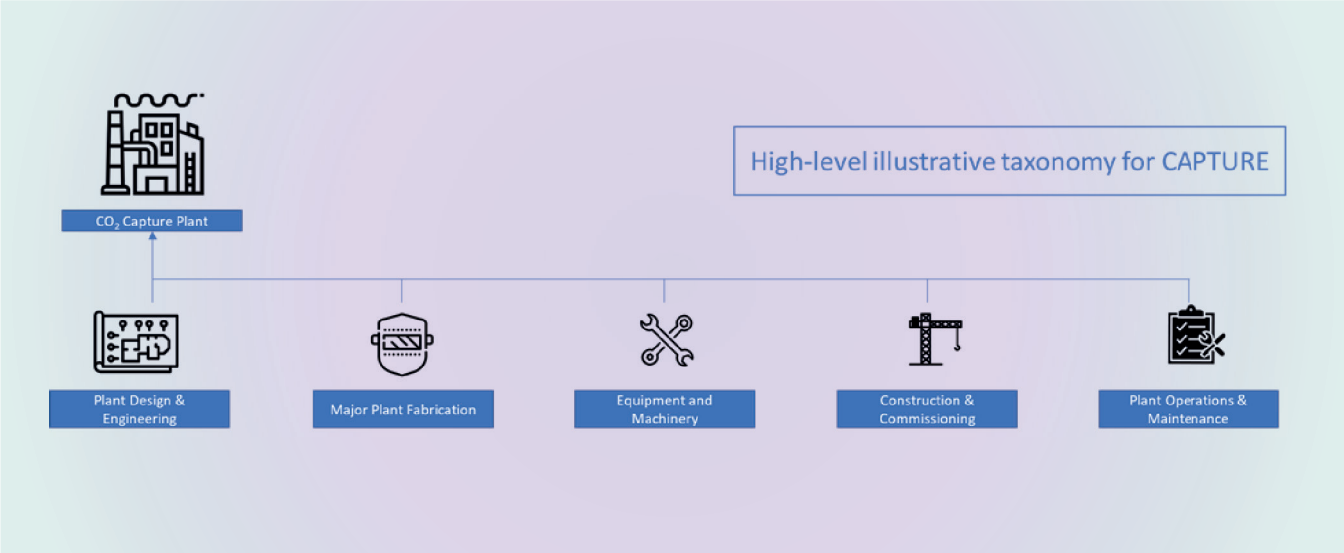
5.1 Overview

Carbon capture is the separation of CO_2 from other gases and/or air, before or after combustion. Most applications after combustion use amine-based absorption systems. Pre-combustion capture is generally for gas sweetening and hydrogen production. Oxy-fuel combustion is an alternative method where oxygen is used for process combustion rather than air.

The UK government has received applications from 41 eligible emitter projects to be approved in Phase 2 of the CCS cluster sequencing process, although it is not clear which projects will be prioritised and, while the competitive process continues, bidders have drawn a veil over the operational insights. The timing of the required future demand for resources, such as design contractors is dependent on the timing of government financial support approval and projects having the necessary maturity to take final investment decisions.

The 41 projects are a mix of industrial, power generation and other projects. While broadly similar in design, there will also be bespoke requirements so standardisation should be the goal where possible. The existing supply chain for the petrochemical and oil and gas industries is well matched for the needs of the capture element of CCS. Core components such as the absorbers and regenerator vessels involve large on and offsite fabrications *(See Appendix E).*

High-level illustrative taxonomy for CO_2 capture



5.2 Plant design & engineering

Market Opportunity	UK Capability	Value and accessibility of opportunity
£2bn - 3bn	●	●

THE FINDINGS

- There is significant overlap in the plant design and engineering of conventional oil and gas upstream and other energy projects and those needed to support CCS.
- The UK has several engineering companies who have successfully supported the oil and gas and petrochemical sectors over several years. They have the skills to manage a CCS project from early design through to implementation.
- Some firms are already embracing the CCS opportunity. Siemens Energy is part of a consortium with Aker Solutions and Doosan Babcock to provide solutions for the UK CCS market[11], building on existing UK capabilities, for example.
- Most of the large UK engineering consultancies have worked on CCS projects from feasibility to pre-Feed/Feed and moving towards implementation.

o Net Zero Teesside (NZT) Power, BP, and partner Equinor awarded contracts to Technip Energies and General Electric in one consortium and Aker Solutions, Doosan Babcock, and Siemens Energy in another consortium, to deliver a comprehensive Feed package over the next 12 months. NZT will help UK firms win CCS contracts in the UK and internationally, supporting the UK further its plant design and engineering capability.

o Wood is to be the integration project management contractor (IPMC) for Humber Zero[12], one of the leading industrial decarbonisation projects in the UK. As the most carbon-intensive industrial cluster in the UK, Humber emits 12.4mn mt CO_2/yr. As part of the scope of work, a multi-disciplinary team from across Wood will facilitate the development and integration of the designs across the Feed packages including interface management, safety studies, licensor selection, and scoping of future services. In addition, Wood will support VPI Immingham and Phillips 66 through the subsequent Feed delivery and engineering, procurement and construction tendering process. This award builds on the feasibility and pre-Feed studies carried out by Wood to support the development of the Humber Zero project.

[11] https://www.energyvoice.com/renewables-energy-transition/348359/aker-solutions-siemens-and-doosan-babcock-team-up-for-uk-ccs-work/

[12] https://www.woodplc.com/solutions/expertise/case-studies/humber-zero-project

THE OPPORTUNITY

- The UK has an early mover advantage through the current CCS programme and an opportunity to be one of the first nations in western Europe to roll out CCS at scale, providing the opportunity to gain valuable insights and experience in plant design and engineering, with the potential for this to be exported.
- The UK government has announced a £1bn Carbon Capture and Storage Infrastructure Fund (CIF), which will support the significant private investment expected by 2030.
- At 10%-15% of total CCS Capex, the UK plant design and engineering opportunity is estimated to be between £2bn and £3bn, indicating a major sales opportunity for the supply chain.

THE CALL TO ACTION

- The UK supply chain is already demonstrating it can secure plant design and engineering opportunities.
- Government decision-making and policies and supply-chain and industry collaboration must continue in order to ensure visibility. This will in turn generate capacity planning.
- Industrial relationships with academic institutions, and research to enhance efficiency in designing carbon capture plants, should be encouraged.

5.3 Major plant fabrication

Market Opportunity	UK Capability	Value and accessibility of opportunity
£3bn - 5bn		

THE FINDINGS

- Carbon capture facilities use similar technology as petrochemical and refining processes. They need absorption and pressure vessels as well as standard process and chemical engineering.
- Major plant fabrication is a significant and valuable element of the legacy oil and gas supply chain. However, production has declined in recent years.

Finished steel demand in the UK has dropped 34%[13] since 1996. Since the mid-1990s UK fabrication capability has declined significantly[14]. The oil and gas fabrication industry in Scotland alone employed around 15,000 people with steelyards at Ardersier, Arnish, Clydebank, Methil, and Nigg, and concrete yards at Ardyne Point, Hunterston, and Kishorn. Most are now closed.

Steel is a cross-border traded product. The UK imports some 6.6mn metric ton (mt)/yr of steel, around 60% of requirements, and exports 3.5mn mt/yr, just under half its production. Steel production is both energy and carbon-intensive. The Emission Trading Scheme (UK ETS) imposes additional costs as the cost of carbon certificates rises, limiting competitiveness and increasing the import of steel with a bigger carbon footprint[15].

And UK fabrication shops have faced substantial challenges in production owing to high energy costs (an increase of c.130%[16]). Steel and material prices have also risen sharply (global steel costs have almost doubled since 2020[17]), making it even harder to compete with imports.

Recently, steel fabricators have turned their attention to the renewables sector, recognising the growth opportunity this presents:

- o UAE-based, but London Stock Exchange-listed Lamprell has signed an MoU with developer NOV to support its delivery of Cerulean Winds' three 1-GW floating wind farms off the West of Shetland and in the central North Sea[18]. UK yards will be engaged to showcase further opportunities for the UK supply chain.
- o Belfast's Harland & Wolff shipyard went into administration in 2019 but it is now celebrating its first major fabrication contract in recent years. Saipem has ordered eight wind turbine jacket structures, worth £26mn[19].

- The deep dive into the fabrication of columns, vessels, ductwork, piping, and other elements, (Appendix A) provides further analysis of this sector. The following survey responses were particularly relevant:

- o The oil and gas supply chain can support CCS requirements as it commands most of

the fabrication capacity gas sector, with only a third of companies surveyed having the ability at this point to support CCS projects.

- However, the specifications of larger components may present a challenge. The modules and pressure vessels required for CCS plants are typically larger than those found in the existing oil and gas supply chain. For instance, typical absorber dimensions range from 12m to 32m in square cross-section, and regenerator vessels can be up to 60m tall. The initial response from the supply chain was high level of capability (60%) in this area. However, when the specific requirements were included, this halved the assessment (30%).

THE OPPORTUNITY

- The high cost of major components such as the compressors mean that major plant fabrication could account for about a fifth of the total.
- The scale of opportunity is supported by the results of the Feed Study for the Petra Nova CCS Project in Texas, indicating a total CCS plant capex of £635mn, for a 1.4mn mt/year site.
- There are 41 CCS projects long-listed in Phase 2 of the government's cluster sequencing process and a significant number will proceed to implementation. Each will need major component fabrication.
- The CCSA supply chain Excellence Report[20] points to improved partnerships between designers, fabricators and manufacturers to develop large transportable modules as an opportunity.
- As the UK is moving ahead of western Europe in deploying CCS, an early mover advantage in domestic fabrication and export could be seized. These capabilities could also be adapted to hydrogen and floating offshore wind, in the UK and beyond.
- Support for UK competitiveness in this area could contribute to local content targets, while growing supply chain skills and capacity.

[13] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/668088/UK_Steel_Capabilities_-_Executive_Summary_-_FINAL_141217.pdf
[14] https://www.energyvoice.com/oilandgas/27245/the-fall-and-rise-of-our-oil-fabrication-industry/
[15] https://committees.parliament.uk/writtenevidence/14920/pdf/
[16] https://www.britishgas.co.uk/energy-price-news.html#caveat
[17] https://tradingeconomics.com/commodity/steel
[18] https://renews.biz/77118/lamprell-signs-fabrication-pact-for-cerulean-floaters/
[19] https://www.harland-wolff.com/news/harland-wolff-is-awarded-major-fabrication-contract/
[20] https://www.ccsassociation.org/wp-content/uploads/2021/07/CCSA-report-Supply-Chain-Excellence-for-CCUS-22-July-2021-1.pdf

THE CALL TO ACTION

- Developing UK fabrication capacity for major plant will not happen by itself:
  - o Increased visibility of CCS opportunities will help companies to plan their investments to capture the value of the opportunity.
  - o Further investigation into the best opportunities, such as mini modules and pressure vessels, will help identify the specific barriers to UK capability and competitiveness. New policies and incentives can support the development of UK capability and capacity.
- Targeted support may be stimulated by developer incentives to use the UK supply chain.
- Offshore wind has had difficulty meeting UK supply chain targets as it has been difficult attracting manufacturers to invest in the UK and then ensuring developers (who are incentivised to compete on cost through the CfD subsidy mechanism for renewables) make use of manufacturing facilities. This problem should be addressed early on in the development of local supply chain targets for CCS.
- The scope for UK industry to supply the right specification steel should be assessed:
  - o EPCs should consider standardisation, including modular components, to reduce costs and make the manufacturing more efficient.
  - o A potential Carbon Border Adjustment Mechanism (a levy on the carbon content on imported goods) may help the UK supply chain become more cost-competitive and stimulate investment.
- Early indication of local content targets and how they will be tied to government contracts will allow time for consultation and for factoring them into procurement and execution processes.

5.4 Equipment/machinery/design & manufacture

Market Opportunity	UK Capability	Value and accessibility of opportunity
£3bn - 4bn		

THE FINDINGS

- The equipment and machinery considered here include the design and manufacture of auxiliary components required to support both plant operation and maintenance and major manufacture and packaging of process equipment - examples being motors, pumps, blowers, compressors, and heat exchangers.
- These components have long been used in the oil and gas sector, with established international brands supporting their manufacture. Most components trade on global markets and are relatively commoditised and serve multiple sectors.
- For example, a Scotland-based company interviewed for this report and a manufacturer of fans, heaters, compressors, blowers, and steam turbines, has over 100 years of export history.
- The CCSA Supply Chain Excellence[21] report and Supply Chain Intervention Strategy[22] concludes that current UK capacity cannot support all elements for more complex CCS process equipment:
  - o CO_2 compressors have a relatively weak UK supply chain with most expertise and products being sourced abroad;
  - o Higher capability, experience, and supply chain readiness exists in the UK for pumps, heat exchangers, gas exchangers, and crossover exchangers.
  - o There is some limited capability in the UK supply-chain regarding CO_2 absorption columns, amine treatment plant and direct contact coolers.

THE OPPORTUNITY

- OEUK has modelled component requirements for all planned CCS projects, with the projected data inclusive of high emitters and peak market requirement of equipment and machinery between 2025 and 2030.
- Examples of the volume of components required between 2025 and 2030 are about 800 heat exchangers and 90 compressors. Procurement begins 18 months in advance, giving a tight timeline for UK capacity to meet this first tranche of potential demand.
- There is significant value in this element of the supply chain, representing about 15%-20% of a total CCS capex of £3bn-4bn.
- There is limited opportunity for the UK supply chain where it is not already active, but there may be an opportunity in niche future requirements.

[21] https://www.ccsassociation.org/wp-content/uploads/2021/07/CCSA-report-Supply-Chain-Excellence-for-CCUS-22-July-2021-1.pdf

[22] https://www.ccsassociation.org/wp-content/uploads/2022/03/CCUS-Supply-Chain-Intervention-Strategy.pdf

THE CALL TO ACTION

- It will be challenging for the UK to develop significant new supply chain capabilities in this area, based on the technology synergies that exist today and the bulk of the major equipment being sourced internationally and from other sectors.
- A key lever in making CCS more cost-competitive and enabling the oil and gas supply chain to move into CCS, is improved technology. Investing and supporting innovations in technology encourages future capacity and may represent an opportunity for small to medium-sized (SME) enterprises that can focus on areas of innovative technology in a more agile fashion.
- CCS technology development is being evaluated in a report by the Technology Leadership Board.

5.5 Construction & commissioning

Market Opportunity	UK Capability	Value and accessibility of opportunity
£5bn - 7bn		

THE FINDINGS

- The procurement pipeline includes 340 contracts for over 260 projects, programmes and other investments. As much as £37bn could be awarded over the next year. The next phase from 2022 to 2025 will require a workforce of up to 4,000 at peak times, including welders, pipefitters, and electricians. As a comparison, the world's largest operational CCS facility at a coal-fired power plant at Petra Nova in Texas at its peak employed 323 workers.
- For its bio-energy plus CCS project, Drax intends to source 80% of the construction materials and services from the UK, indicating confidence in UK capability.
- The Infrastructure & Projects Authority (IPA) and HM Treasury have published the 'National Infrastructure and Construction Procurement Pipeline 2020/21,' which looks a few years ahead.
- There may be significant capacity constraints as competition for materials and skilled labour and EPC from other sectors grows fiercer.

THE OPPORTUNITY

- The market opportunity is estimated to be £5bn-£7bn for constructing and commissioning CCS capacity.
- However, despite capability existing, current capacity may be insufficient to cope with demands from a growing range of infrastructure projects. In addition, these competing sectors can provide more visibility and assurance of project timelines which may impact the relative attractiveness of CCS.

THE CALL TO ACTION

- In the next ten years, the UK supply chain has the chance to collaborate on developing the skills and the workforce needed to meet demand. A barrier to capacity highlighted in several survey responses was the lack of skilled labour. Using shared skills academies across the UK could help this by building a pipeline of talent.
- CCS projects will be coming at a busy time for the infrastructure market, as noted by the National Infrastructure Strategy. The availability of UK labour and skills will be limited. Engagement with specific organisations such as RGU Energy Transition Institute, among others, to qualify and support research into this area of the supply chain may support a better understanding of capacity and relevant actions to improve.

5.6 Operations & maintenance (O&M)

Market Opportunity	UK Capability	Value and accessibility of opportunity
Opex	●	●

THE FINDINGS

- To meet the UK's CCS and net-zero targets it is likely that a strong proportion of the 41 Phase Two projects will reach the operational phase, which presents an opportunity for the supply chain to offer O&M services.
- There are strong synergies between CCS and oil and gas production, meaning that many jobs and infrastructures are interchangeable.
- Many power generation and industrial companies planning projects, or retrofitting their facilities, may not have the internal capabilities to manage certain specialist chemical and process engineering elements of a CCS plant. These skills are core to the existing oil and gas supply chain.
- EPC companies will be well placed to capitalise on this market thanks to the deep insight they have gained through the project design & implementation lifecycle.

THE OPPORTUNITY

- The CCS capex estimation for construction and commissioning is £5bn-£7bn, indicating also a significant opportunity for plant O&M, albeit spread over a longer period. As operations are not expected to start until at least the seconds half of 2025, the market has sufficient time to prepare.
- O&M demand would normally be met locally owing to the long-term and fixed location of the services. Given the strong existing oil and gas capability and the time available to plan for these services, this is a big opportunity for the UK oil and gas supply chain.
- Stakeholder insights indicate an opportunity for partnerships between technology and EPC companies for O&M. This may enable shared learning across the sector, helping to improve the CCS area of the supply chain.
- This may also represent an opportunity for sub-contract work for SMEs (small to medium enterprises) to provide specialist or local services, especially in less established locations.
- The CCS technology companies will also offer elements of O&M with their licences to enable projects' ongoing access to intellectual property and process/chemical improvements.

THE CALL TO ACTION

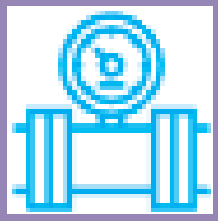
- The operations and maintenance of CCS plants will include regular servicing, planned shutdowns, and continuous improvement of facilities.
- As projects are developed, the partners should consider whether expertise and skillsets from oil and gas are transferable to CCS. They should ensure that training and development opportunities are provided while the UK moves through a period of high construction in the 2020s and 2030s.
- The supply chain is well placed to capitalise, given the necessary skills, capabilities, and commercial terms to deliver these services.

6. Transport & Storage

Transport involves the compression of the captured CO_2 into a dense gaseous or liquid phase and transportation to the storage facility, by pipelines, ships, or even rail/road tankers. The best method depends on the volumes to be transported and the relative locations of the capture and storage facilities, so each CCS project/cluster will have its own design. Transport infrastructure, like storage, will often be shared by a number of upstream projects.

Across the Track 1 clusters, there are differences in design. The East Coast Cluster has separate onshore and offshore pipelines, that range from gaseous to dense phase at the Teesside or Humberside locations onshore, and then dense phase pipelines from each of the cluster locations to the shared offshore infrastructure. All the pipelines in the East Coast cluster project are new. HyNet is installing new onshore pipelines but looking to re-use existing offshore pipelines. This is also the case with the Acorn Project in Aberdeenshire. Emerging clusters such as South Wales and Project Cavendish on the Thames Estuary are being developed without access to local offshore storage, and shipping solutions are being explored by both.

Repurposing of pipework for CO_2

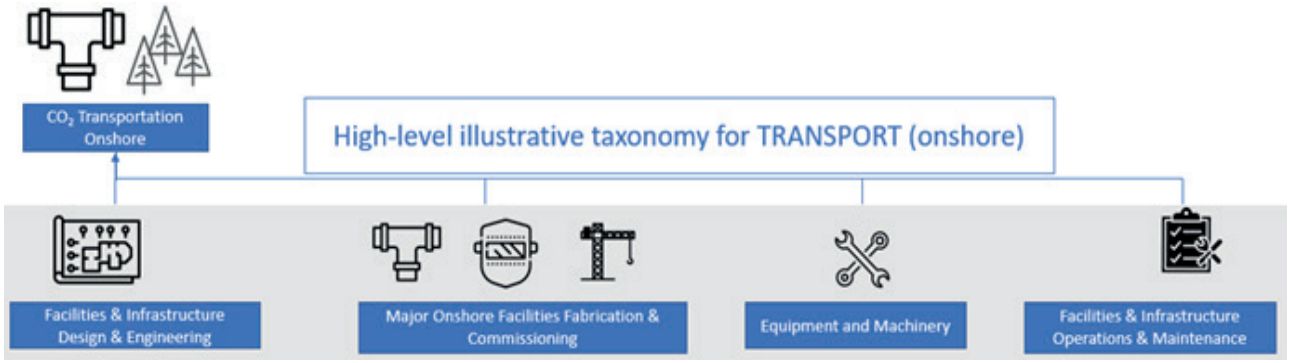


Existing gas pipework can be repurposed for CO_2 transport, but it is also being considered for the transport of hydrogen. Efforts have been made to address and resolve the key issues relating to the safe routing, design, and construction of onshore pipelines:

- National Grid progressed the £8mn COOLTRANS (CO_2 Liquid pipeline TRANSportation) research programme to transport CO2 from industrial emitters to offshore locations for underground storage.
- The COOLTRANS research programme brought together major technical capability in UK academic and industrial organizations, co-ordinating research to provide a fast track for the identification and application of key learning to CO_2 pipeline projects.

The high-level taxonomy of transport has been characterised as either onshore or offshore.

High-level illustrative taxonomy for CO_2 transport (onshore) and CO_2 transport (offshore).
A complete high-level taxonomy is available in Appendix B



6.1 Storage overview, including taxonomy

Storage: this is where the CO_2 is injected into sub-surface formations, where it disperses within pore space and is contained within the subsurface by impermeable sealing layers. This report assumes the first wave of CCS projects will be depleted oil and gas formations or saline aquifers mostly offshore. These will require the activities listed under 'Wells, subsurface and reservoir engineering (Section 6.4) which is essentially making these ready to receive CO_2. This would include design and EPC activity and would use the same equipment that is used for drilling and plugging wells.

Once CO_2 has been stored it will require constant subsurface and reservoir MMV (section 6.6). This is the operational phase of the storage site, even if the wells are plugged and abandoned. The activity would include seismic and seabed CO_2 leak monitoring. In Europe, storage is expected to be mostly offshore. A variety of rock formations can be used, including:

Saline aquifers

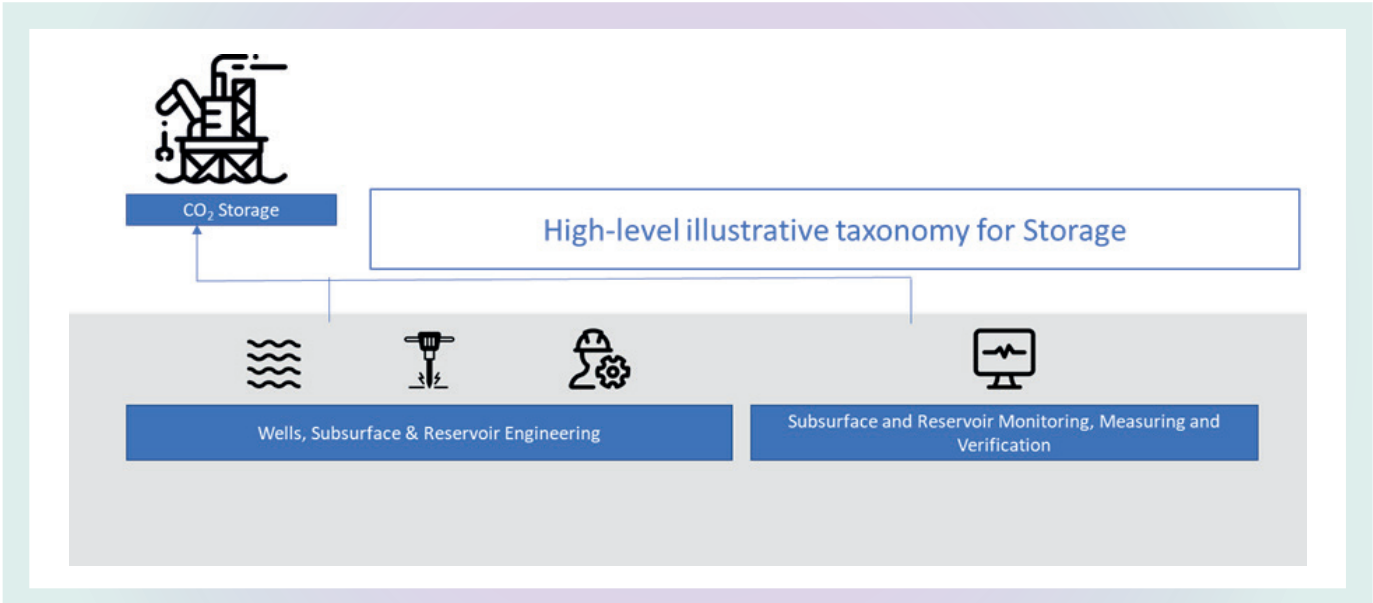
In Europe, Sleipner uses a large local saline aquifer to store CO_2, and further afield in the USA, the Illinois Basin Decatur Project also used a deep saline aquifer. Saline aquifers require extensive MMV and surveying to assess the integrity specifically around the caprock/seal, representing an opportunity for the supply chain.

Depleted reservoirs

Depleted oil and gas reservoirs have proven containment, injectivity (owing to high permeability in production), and capacity abilities (thanks to high volume storage). They are also a business development opportunity for the supply chain: the challenge with using oil and gas reservoirs is the integrity of legacy wells and how they were decommissioned.

The high-level taxonomy of storage has been characterised as:

Fig 16. High-level illustrative taxonomy for CO_2 storage, a complete high-level taxonomy is available in Appendix B



Note

In reviewing the section below, the reader should note:

(1) The taxonomy assumes CO_2 storage has already been identified and assessed. Any new CO_2 storage sites would require geological assessment and this activity has not been included in the taxonomy of this report.

(2) Although not a separate L2 activity, the report includes a section below on marine and subsea contractors. These activities are part of wells, subsea and reservoir engineering, but as a specialised area of the supply chain dependent on skills and experience gained in oil and gas, it merited further assessment.

6.2 Pipeline transport

Market Opportunity	UK Capability	Value and accessibility of opportunity
£2 – 3bn Pipework and supply installation	◑	◑

THE FINDINGS

- For the UK clusters, a transport solution is needed to move CO_2 from multiple capture points at different industrial emitters, through an onshore solution and then offshore to the chosen storage location. The most cost-effective engineering solution for transport between capture and storage is a key design question for the respective clusters and will reflect the volume of CO_2, the distance it must travel, and the presence and suitability of existing infrastructure.
- The clusters' decisions on design will depend on the form in which the CO_2 is to transported: i.e., gaseous, or dense phase, and the impurities within the CO_2 stream. These decisions will impact pipe specifications, possibly creating complexity in the procurement process.
- The clusters are also exploring whether existing infrastructure can be reused, taking account of whole life asset cost. In many cases, new pipelines will be needed both on and offshore, in particular, where there is no suitable onshore pipework connecting emitter sites to offshore storage. UK clusters have been engaging the market to understand the capability and capacity for pipeline construction and repurposing existing infrastructure.
- This section will focus on new-build pipeline given the greater supply chain potential associated with this. This section considers:

o Onshore: pipe supply; EPC for pipe installation, pumps, specialist installation equipment e.g., tunnel boring machinery.

o Offshore: pipe supply; marine pipe laying capability

- Over the last 50 years, the UK has built up extensive expertise in offshore oil and gas pipelines. A recent example is the Clair Ridge project (2018) which created a new installation of a 5.5-km, 22-in oil export pipeline tying into the Clair Phase 1 export pipeline.[23]
- EPC works for pipe installation are within the scope of services of existing UK EPC companies and there is confidence in UK supply chain capability for this.
- However, in terms of pipe supply, procurement in recent oil and gas projects and transmission and distribution projects has been from Asia and Europe rather than the UK. There is low confidence that the pipeline required can be sourced through the UK supply chain.
- Steel is a cross-border traded product. The UK imports some 6.6mn mt/yr of steel, around 60% of requirements, and exports 3.5mn mt/yr, just under half its production. Steel production is both energy and carbon-intensive. Decarbonising steel-making under the UK ETS imposes new costs and reduces the ability of domestic companies to compete with international competitors and can instead lead to an increase in the import of steel[24].

THE OPPORTUNITY

- Both Track 1 clusters are now running market engagement processes. The East Coast Cluster has recently announced that Genesis will deliver more than 250 km of subsea pipeline, two landfalls, and a subsea injection system connected to six wells, while Costain will deliver the onshore CO_2 gathering pipeline that will serve Teesside.
- Both new and repurposed pipelines will require support via activities such as design, fabrication, commissioning, and O&M.
- The highest value opportunity is the manufacture and supply of new pipelines for both onshore and offshore, estimated at £2bn. But there is limited confidence that the UK has the capability to compete with imports to capture this opportunity, especially for dense phase transport which will need higher specification pipe.
- Onshore EPC for pipelines is also a significant opportunity. The UK has this capability but will compete with a wider set of construction activities for key skills such as welding.

THE CALL TO ACTION

- The UK is well-positioned for the EPC component of the onshore and offshore pipelines.
- While onshore and offshore pipe supply is a significant opportunity area in terms of market value, there are already recognised global pipe manufacturing players who would make it challenging to establish the UK in this area, even with significant intervention.
- Mechanisms to support UK competitiveness may include carbon border adjustment mechanisms or carbon product standards.

[23] https://www.offshore-technology.com/projects/clair-ridge-project-shetlands/

[24] https://committees.parliament.uk/writtenevidence/14920/pdf/

6.3 Ship transport of CO_2

Market Opportunity	UK Capability	Value and accessibility of opportunity
 **£ uncertain**		

THE FINDINGS

- The primary source of CO_2 transportation in Track 1 clusters will be via onshore and offshore pipelines.[25]
- While costs of CO_2 pipelines are generally lower, other transportation solutions will be required where a connection with storage is too distant to justify pipeline investment. In these cases, marine transport will be required.
- For example, emissions from the southeast industrial clusters will require transportation to the geological storage capacity further north. The Acorn Project has signed an MoU with Project Cavendish (a collaboration between Arup, VPI, National Grid Ventures, Shell, SSE Thermal, and Uniper) to receive CO_2 at Peterhead Port in Scotland shipped from the planned production site at the Isle of Grain.[26]
- Another potential driver for marine transport is the UK's geological storage capacity which can accommodate CO_2 from other regions without any.
- As of spring 2022, no end-to-end CO_2 tanker transport solution exists globally. However, development across the value chain is underway. In Norway the Northern Lights project is focused on a full-scale solution connecting various locations in Europe and converting former LPG carriers for CO_2 transport. The ships will be built by Dalian Shipbuilding Industry Co (DSIC), based in China, and will be ready for delivery by mid-2024.
- Marine CO_2 transport relies on converting old LNG and LPG carriers, a sector where China and South Korea have a structural cost advantage as well as shipyard capacity. UK capacity in this sector has declined, with the focus on defence contracts.
- The government has announced a refreshed National Shipbuilding Strategy[27] (March 2022). The strategy articulates £4bn of government investment to galvanise and support shipyards and suppliers, including better access to finance, vital skills-building, and crucial funding for research and development into greener vessels and infrastructure.
- While this is positive for the wider shipbuilding industry, the strategy and any associated support are not focused on CO_2. A more likely investment area for UK shipbuilding is service operations vessels for offshore wind, given the huge scale of UK capacity and ambitions in this area.

THE OPPORTUNITY

- The need for ships will drive new-build or significant retrofit investment to develop this capacity.
- The substantial storage capacity in the UK could enable the import of CO_2.
- As highlighted, large-scale shipbuilding is being carried out globally but not currently in the UK. Notwithstanding the UK shipbuilding strategy, it is not expected that the UK supply chain will be competitive or that CO_2 transport vessels will be a priority for UK shipbuilders.
- Any development of significant new capability and capacity would need to be proven to give confidence to the market and hence would take several years. Given the continued cost disadvantages for the UK, this is not considered an area of opportunity.

THE CALL TO ACTION

- A specific call to action has not been identified in this area as this is not considered a viable area for UK supply chain opportunities.

[25] It is acknowledged that transportation of CO_2 includes road tanker transport but at the scale required would be uneconomic it has not been explored in this report.

[26] https://theacornproject.uk/2021/10/12/scottish-cluster-set-to-support-thames-estuary-decarbonisation-by-shipping-co2-emissions-through-peterhead-port/

[27] https://www.gov.uk/government/publications/refresh-to-the-national-shipbuilding-strategy

6.4 Marine loading & offloading

Market Opportunity	UK Capability	Value and accessibility of opportunity
 £ uncertain		

THE FINDINGS

- The CCSA CCUS Delivery Plan - 2035 report draws a Global Leadership scenario where the UK takes a leading global role in CCS, allowing for the marine import of CO_2. This would drive significant import potential and hence a requirement for loading and offloading facilities to manage the domestic and non-domestic demand. In this scenario, the design, engineering, fabrication, construction, and commissioning of offloading facilities will be needed.
- Marine loading and offloading does exist for the LNG sector[28] which has many synergies.
- Existing technology and experience in LNG can be transferred to liquefied CO_2 transport but will require some augmentation.
- The port at Peterhead in Aberdeenshire will be an integral part of offshore storage development with the potential loading of CO_2 captured from remote clusters such as South Wales or transported to the UK by ship and feeding the offshore pipelines. In addition to UK projects, the scope to send CO_2 by ship to Norway has also been identified to avoid the curtailment of projects in the event of pipeline/store failure.
- Increasing reception capacity will come with imports of CO_2 from other regions. At this stage, it is not clear whether the government supports a revenue stream from imports; or whether ambitions will be limited to domestically captured CO_2.

THE OPPORTUNITY

- The UK will likely have a domestically driven demand initially for these facilities to connect clusters with established geological storage areas. Having an import terminal is not a certainty although these are being developed in Norway and may eventually play a role in the UK.

THE CALL TO ACTION

- This is an area of the supply chain that will need to be developed if the UK wants to make money from importing and storing CO_2. This is a strategic decision whose outcome will dictate the appropriate supply-chain actions.
- If the UK decides to import CO_2 it should consider capitalising on the UK's freeport initiatives[29] to build out the necessary infrastructure, much of which will have direct links to the heavy lifting and steel fabrication elements of the supply chain.

[28] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1006628/DUKES_2021_Chapter_4_Natural_gas.pdf

[29] https://www.gov.uk/guidance/freeports

6.5 Wells, subsurface & reservoir engineering

Market Opportunity	UK Capability	Value and accessibility of opportunity
£1 – 2bn Overall Storage market opportunity	●	●

THE FINDINGS

- For the purpose of this report, wells, subsurface and reservoir engineering are the activities required to prepare an identified CO_2 store for operation through design, drilling, injection, and other activities.
- CCS is viable in the UK owing to the CO_2 storage capacity created by the legacy oil and gas industry. The use of depleted subsurface reservoirs or saline aquifers for CO_2 storage is the final step in the CCS value chain. Unique synergies between CCS and oil and gas put the existing supply chain in a strong position in terms of skills and equipment to deliver this service.
- Equinor has been successfully storing CO_2 for over 20 years. This represents lessons learnt and supply chain transfer opportunities for firms operating in the North Sea.
- While there are significant synergies there are some notable considerations that the CCS supply chain will need to consider:
  - The chemistry of materials: CO_2 has a corrosive effect on steel when dissolved in water and it will also affect the cementation of the well casings.
  - Well decommissioning technology: to prevent the migration of fluids into the annulus of the well or to the surface.
  - Subsurface characterisation: understanding the risks associated with CO_2 plume migration within the formation.
  - Well integrity and interventions: wells will have to be designed to inject CO_2 or produce brine if using a saline aquifer under variable operating conditions, such as high pressures and low temperatures. Equipment used to conduct well interventions for well maintenance and integrity screening will have to withstand sub-zero temperatures.
- The UK is well placed to understand and adapt to the new requirements of CCS. The Centre of Excellence for Reservoir Engineering at Schlumberger's Oxfordshire site has been considering CCS requirements and will continue to apply new learnings to products and services.
- In 2019, the wells, subsurface, and reservoir supply chain made up about a fifth[30] of the total UK upstream oil and gas supply chain turnover, representing 221 companies and 6,000 employees.
- There are a multitude of CCS well services and engineering initiatives, including the Net Zero RISE project, aimed at reducing the cost uncertainty associated with geological storage and de-risking the delivery of capacity offshore.
- There are significant advancements in technologies that secure wells against annulus CO_2 leakage: expandable barriers and anti-corrosion techniques (e.g. Welltec).

[30] EY UK Energy Services Overview, https://assets.ey.com/content/dam/ey-sites/ey-com/en_uk/topics/energy-resources/how-accelerating-energy-transition-will-shape-the-industry/ey-uk-energy-services-overview.pdf

THE FINDINGS (CONTINUED)

- Interviewees were confident that the relevant technology exists, with individuals noting that 'all the drilling technology and kit is directly aligned with that in the oil and gas supply chain'.
- The NSTA will launch an upstream licensing round in the autumn which will consider the impact of new production on the environment as it puts continuing exploitation of domestic hydrocarbons resources as a central point of a new energy security strategy. This may see more interest in new and higher-value exploration than in the emerging CCS sector.
- The timing and cost of CCS projects, when competing with legacy oil and gas, will need some thought. Deploying drilling infrastructure for CCS is not something that can be done and undone at speed. TransOcean's Enabler, a semi-submersible drilling rig, is under contract with Equinor until 2024, at $441,000/day, which puts into perspective the costs of drilling in CCS projects.
- The deep dive into offshore storage development (Appendix A) provides further analysis of this sector but the following survey responses were particularly relevant:
  - o The capability exists in supporting the necessary offshore development for CCS. Most survey respondents support the oil and gas sector (93%), and a high number (67%) already support CCS projects. So the supply chain has already begun to pivot to the emerging CCS requirements.
- Commodity markets for raw materials are traditionally volatile and raw materials are key in the equipment required for subsea development. Subsea cabling is a high-demand component and will inevitably be a risk to project delivery if demand should outstrip supply.
- 'Christmas trees', which are made in the UK, will be a vital component for all CO_2 injection and brine production, as they will control or prevent the migration of fluids from the subsurface to the surface by sealing the well. In a CCS environment, they would need to be designed to work in varying operating conditions, CO_2 phase behaviours, and temperatures.

THE OPPORTUNITY

- The UK is well positioned to capitalise on the £1-£2bn market opportunity of this area in CCS as these priming activities include drilling and injection.
- Stakeholders say demand for 'christmas trees' is forecast to be high across oil and gas and the CCS market. Investment in the manufacturing of these items will help the UK to meet domestic demand and increase export opportunities.
- Early identification and commitment to subsea CCS projects will allow the supply chain to forecast demand for vital materials and equipment, providing the opportunity to purchase at scale and in partnerships.

THE CALL TO ACTION

- Develop a 'basin' led planning approach to improve demand visibility and ensure that co-located requirements across different energies are efficiently serviced with the resources required to deliver CCS during high demand periods. Potential resource constraints have been identified as the NSTA anticipated new licensing round in oil and gas, and key CCS equipment is sourced from global markets with significant lead times and often in scarce supply.
- Commit and provide early visibility to subsea CCS projects, allowing potential partnerships to take advantage of economies of scale purchasing and forecast demand for critical CCS materials and components as soon as feasible. A co-ordinated sourcing strategy will allow an aggregated approach to global markets for equipment such as subsea cabling.

6.6 Marine & subsea contractors

Market Opportunity	UK Capability	Value and accessibility of opportunity
 **£1 – 2bn** Overall Storage market opportunity		

THE FINDINGS (CONTINUED)

- Marine and subsea contractors are part of wells, subsea and reservoir engineering. As a specialised area of the supply chain, dependent on skills and experience gained in oil and gas, it merited further assessment and therefore has also been subject to a deep dive (Appendix A).
- This subsector includes marine/subsea contractors, heavy lift/pipelay contractors, floating production storage units, subsea manifold/riser design and manufacture, marine/subsea equipment, and subsea inspection services.
- In 2019 there were 184[31] marine and subsea companies employing around 20,000 and servicing the UK and overseas markets.
- The oil and gas industry's need for marine and subsea engineering has driven the development of a strong and flexible UK capability.
- Marine and subsea turnover grew in 2019, for the first time since 2014[32]. This was driven by the equipment subsector (17% growth) with an upturn of orders and successful conversion of these orders during 2019, with several companies noting that the order backlog was returning to historical levels (pre 2014 oil price decline).
- The equipment in marine and subsea is sourced and dispatched from global manufacturers, often with substantial lead times. Capacity planning needs to be done well in advance and this is especially important if the equipment services multiple energies.
- The constraints caused by Covid-19 have deferred some key projects such as CNOOC's Buzzard Phase 2 and Neptune Energy's Seagull, pushing out timelines and capacity requirements. The backlog of maintenance and inspection for the existing assets in the subsea sector will use some of the available capacity in the immediate future.
- Surveys have shown that rising global demand has made it harder to access equipment such as vessels. As described above, vessels and additional offshore equipment commonly used in other energy areas need advance booking.

THE OPPORTUNITY

- The storage element of CCS could cost £1bn-£2bn, of which marine and subsea contractors are a significant component.
- Through stakeholder interviews, it was noted that marine and subsea contractors have traditionally been agile and responded to fluctuating demand. Stakeholders are very confident that this area of the oil and gas supply chain can meet the future demand created by CCS and so secure the opportunity.

THE CALL TO ACTION

- There is sufficient capability: there is an established network of marine and subsea contractors that respond to demand and can pivot into CCS contracting from oil and gas, gas processing and associated marine activities. There will be high capability and capacity for CCS contracting if these firms make CCS their priority.
- Develop a 'basin' led planning approach to ensure that co-located requirements are efficiently serviced. Including marine and subsea contractors in early-stage planning will help ensure there is enough supply.
- A co-ordinated sourcing strategy will allow an aggregated approach to global markets for equipment, such as vessels, and so avoid shortages.

[31] EY UK Energy Services Overview, https://assets.ey.com/content/dam/ey-sites/ey-com/en_uk/topics/energy-resources/how-accelerating-energy-transition-will-shape-the-industry/ey-uk-energy-services-overview.pdf

[32] EY UK Energy Services Overview, https://assets.ey.com/content/dam/ey-sites/ey-com/en_uk/topics/energy-resources/how-accelerating-energy-transition-will-shape-the-industry/ey-uk-energy-services-overview.pdf

6.7 Subsurface & reservoir monitoring, measuring & verification

Market Opportunity	UK Capability	Value and accessibility of opportunity
Opex		

THE FINDINGS (CONTINUED)

- The subsurface and reservoir monitoring, measuring and verification part of the supply chain is defined in this report as activities required to support the ongoing maintenance of operational, plugged and abandoned CO_2 stores, including seismic and seabed CO_2 leak monitoring. Appendix A includes the deep dive assessment for this element of the storage supply chain.
- The UK has an estimated total storage capacity of 78 gigatons, one of the largest in Europe.
- When CCS projects move into the operational phase, likely between 2025 and 2030, CO_2 will require continuous MMV.
- In 2019, the reservoir supply chain comprised 3% of the total UK upstream oil and gas supply chain turnover, in economic terms, and was represented by 56 companies based in the UK employing just over 4,000.
- The supply chain for subsurface and reservoir management in CCS is very similar to the oil and gas sector with stakeholders confident it can meet any demand created by CCS.
- Reservoirs that store CO_2 require monitoring for fluid migration. The ability to understand the migration behaviour of CO_2 in the shallow subsurface and faults is essential for CO_2 detection and migration via seismic monitoring services. Seismometers are used to monitor subsurface behaviours such as abnormalities caused by the process of injecting CO_2, to detect anything that could cause CO_2 migration or a seismic event. Continuous monitoring and verification technology will be paramount in ensuring that CO_2 remains in the reservoir.
- New technologies to address this have already been developed in the supply chain, such as the Cuttlefish Carbon Guard developed by TenzorGEO. This is an advanced passive seismic technology that is automated, low-cost, and able to monitor the integrity of the reservoir. This is especially important when there are competing seabed users, such as an offshore windfarm above a CO_2 store.

This is especially important when there are competing seabed users, such as an offshore windfarm above a CO_2 store.

THE OPPORTUNITY

- Subsurface and reservoir management services have been carried out extensively for oil and gas, and therefore the capability is well established in the UK and capable of pivoting naturally to CCS. There is great potential for the UK supply chain to become a world leader in this area.
- Stakeholders highlighted the criticality of asset integrity to the CCS sector, with the opportunity for the UK to lead the way in terms of assessing and monitoring integrity through asset lifetimes, managing, monitoring, and evaluating asset life extension.
- MMV activity will continue to occur up to 10-20 years after injection of CO_2 has stopped, representing a long-term opportunity.
- As the CCS sector develops, the requirement for maintenance services including seismic monitoring, repairs and maintenance, and data management will increase. To give one example of value, the Acorn project in Scotland will require about £10-£12mn/yr in monitoring services.
- The current services providers are working internationally as there are not enough opportunities now. Expanding and moving skills from the oil and gas industry to CCS is an opportunity to grow the UK offering to service national and international CCS projects.
- There is an opportunity to develop new technologies to allow for multiple uses for the same seabed without disturbing crucial activities e.g., monitoring CO_2 above offshore windfarms.

THE CALL TO ACTION

- A specific call to action has not been identified in this area as there is sufficient capability and capacity identified in this and there is the agility to flex to demand.

[33] EY UK Energy Services Overview, https://assets.ey.com/content/dam/ey-sites/ey-com/en_uk/topics/energy-resources/how-accelerating-energy-transition-will-shape-the-industry/ey-uk-energy-services-overview.pdf

7. Conclusions and next steps

There are some common features that would support UK businesses to achieve the maximum potential from CCS rollout in the UK and internationally.

1. Encourage industry and supply chain collaboration on visibility and planning – particularly for fabrication, development of storage, and transport

A consistent theme throughout the research was a call for greater visibility on volume and specification of requirements to enable confidence and planning within the supply chain, especially for participants not directly connected to the main CCS projects. This leads to the following recommendations:

Establish a central data store or tool to provide visibility of the expected demand and specification for CCS-related goods and services.

For marine and offshore services, adopt a planning approach that ensures that co-located requirements in different energies have efficient access to global markets for key plant and services.

2. Create a clear industry classification system for products and services

A single, clear consistent way of describing the supply chain for CCS would be valuable, improving collaboration and understanding.

3. Work to develop domestic skills

Two areas of the CCS supply chain cover a major slice of capital expenditure but where the capability and capacity of the UK supply chain is uncertain. These areas are major plant fabrication for capture; and onshore and offshore pipeline manufacture and supply. With the procurement process for these areas expected to take place 2022-24, early action will be needed to understand the UK opportunity. As such, key recommendations for policymakers to consider are:

- Where there is the greatest opportunity in areas such as major plant fabrication, such as mini-modules and pressure vessels, incentives might be needed to develop a home-grown industry.
- Local content targets and how they will be linked to government contracts should be set early, to inform the procurement and execution processes.

Supply-chain targets in offshore wind have had to face the twin challenges of first enticing manufacturers to the UK, and then ensuring developers (who are incentivised to compete on cost through the contracts for differences (CfD) mechanism) use UK manufacturing facilities. Lessons from this should be applied to local supply chain targets for CCS.

The offshore wind industry shows how a supply chain capability may be developed to meet emerging demand. Making CfD support dependent on UK supply chain development plans, followed by scrutiny of a final investment decision, is one approach. The UK supply chain and economy have also benefited from targeted support, such as investment in port infrastructure.

4. Quantitative capacity planning which considers the aggregate demand of other energies on the supply chain, particularly on workforce and skills

The North Sea Transition Authority's announcement of a new licensing round this Autumn will bring renewed competition for the resources needed to support projects in the early stages. The supply chain has some capacity, but with profitability now higher in the oil and gas sector, supply-chain availability might be squeezed. Being easily switchable from oil and gas to CCS means that resources will be directed to the most profitable sector. If too many projects come to market in a short period, costs will rise and deadlines will slip. This risk can be reduced by:

- Reviewing and aligning the results of CCS market engagement with the other energies' market engagement strategies. At this stage, collaborative work is possible and a realistic picture may develop.
- Planning strategically in areas such as construction and commissioning and in design and engineering. CCS projects will be coming to the market at a time of intense energy infrastructure build and the economy more broadly, as set out in the National Infrastructure Strategy.

5. Maintain momentum

The supply chain has stressed the importance of capitalising on the momentum that CCS has gathered since the cluster projects and the confirmation of funding support for Track 1 projects were announced. This is very different from the last government effort to advance CCS. Track 2 project submissions could be approved by the end of the year. The net-zero targets mean more cluster projects will be needed by 2035.

Government and industry will need to maximise the opportunity. Demand will not be met without clear planning, so communication is key. While some links in the supply chain already have both capability and capacity, others will need support. We are at the point now where these building blocks can still be put in place. But this time is limited, especially for Track 1 clusters.

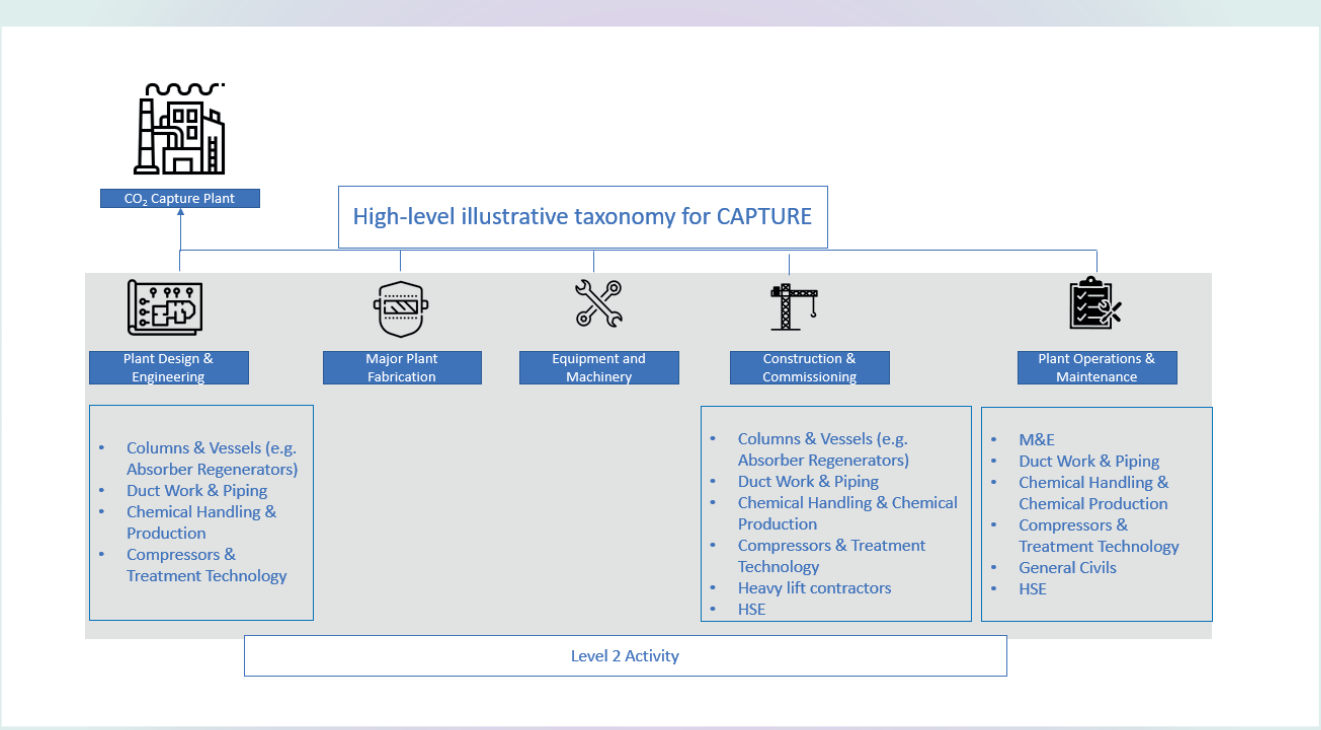
8. Appendix A: Deep Dives

Deep Dive 1: Fabrication of columns, vessels, ductwork, piping and other components

Introduction & context

Fabrication comprises 15%–25% of total Capex with initial interviews suggesting that the UK supply chain does not have a strong competitive position. To test these hypotheses a survey was sent to known fabrication shops and suppliers to gather further information on their capability, capacity, barriers, and levers to increase capacity in response to UK demand.

High-level illustrative taxonomy for capture, of which Fabrication of Columns, Vessels, Ductwork, Piping, and Other Commodities are Level 3



Percentage of HQ location of survey respondents

Headquarter Locations	
Scotland	24%
Northwest England	6%
Northeast England	29%
Midlands	12%
Southeast England	29%

Answers we sought from targeted stakeholder engagement and survey

- What is the UK's capability for the fabrication of columns and vessels, ductwork, and piping?
- How do the UK fabrication shops feel about scale-up/reopening/diversifying to satisfy new demand?
- What are the levers and barriers to increasing capacity?
- Can UK content targets, set by the NSTD, of 50% local content and 30% locally sourced technology be met?

Summary survey findings

The oil and gas supply chain can support CCS requirements

Figures on the following page confirm that survey respondents had capabilities relevant to this survey. As expected, current fabrication capacity is predominantly focused on the oil and gas sector, with only a third of companies surveyed having the ability at this point to support CCS projects.

However, specifications of larger components may present a challenge

The modules and pressure vessels required for CCS plants are typically larger than the commercial vessels used for compressed gas in the existing oil and gas supply chain. For instance, typical absorber dimensions range from 12m to 32m in square cross-section, and regenerator vessels can be up to 60m tall.

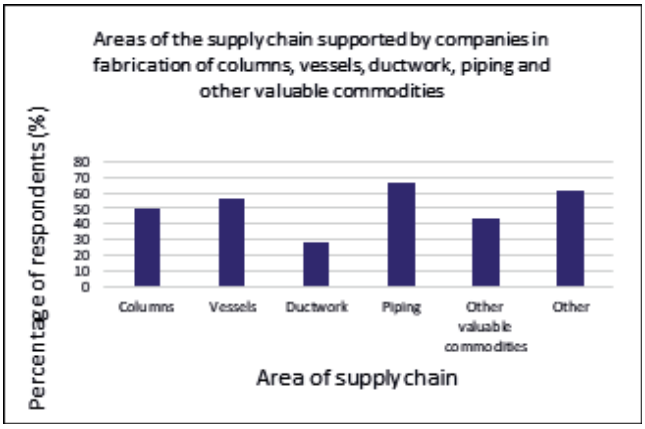
The initial response from the supply chain indicated a high level of capability (60%) in this area. However, when the specific requirements were included, the assessment halved to just 30%.

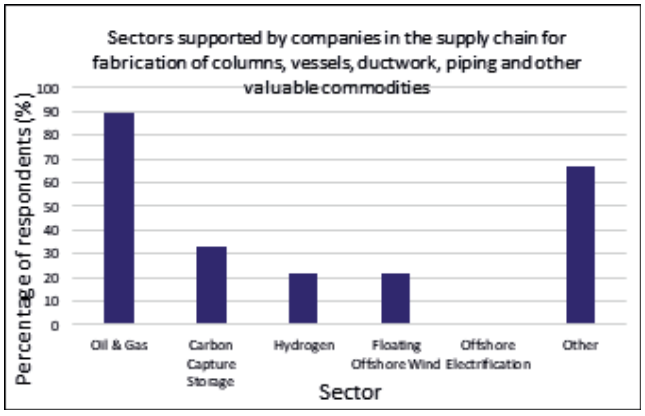
Some investment is required for supply chain participants to support CCS projects

All survey respondents identified the need for additional investment to adequately meet future CCUS requirements. At one level, funding was anticipated at comparatively low levels to provide required equipment, technology, and skills. More significant financing was foreseen for those requiring to expand and enhance facilities and infrastructure.

Areas of the supply chain supported by companies in the fabrication of columns, vessels, ductwork, piping, and other valuable commodities. Other areas from respondents included; tanks, modules, steelwork, offshore secondary steel structures, large diameter tubulars, and crane beams.

Sectors supported by companies in the supply chain for fabrication of vessels, columns, ductwork, piping, and other valuable commodities. The majority are active in the oil and gas sector (89%). Other sectors from respondents included; nuclear, pharma, food & drink, defence, tidal generation, petrochemical, construction, energy from waste, renewables, marine, biofuel, industrial water treatment.

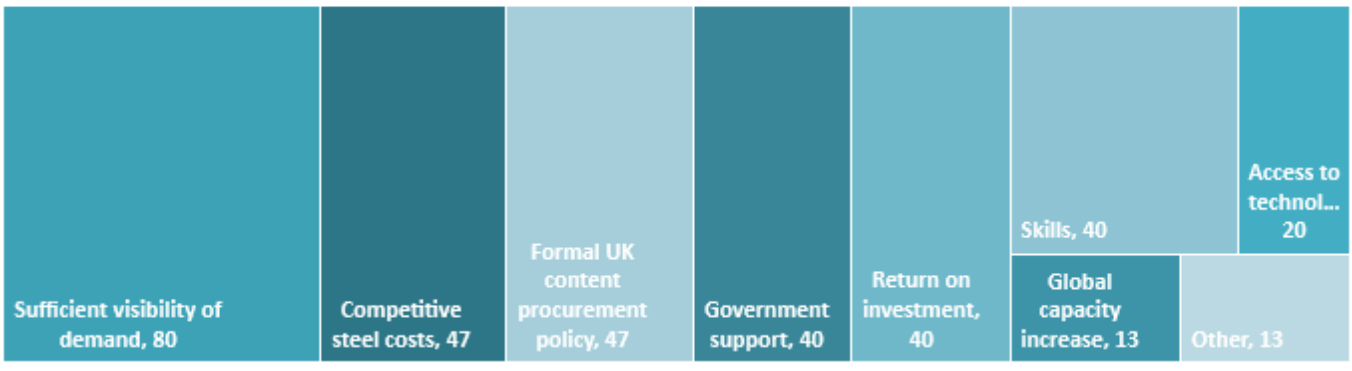




In some cases larger investment was indicated (up to £5mn), this related to undercover facilities, a call-off hub, and related equipment.

As the figure below highlights, a range of factors are needed to increase capacity:

Figure 13 - Factors that would enable an increase in capacity for companies that support the supply chain for fabrication of columns, vessels, ductwork, piping and other valuable commodities (% of respondents)



Demand visibility is a key factor in increasing capacity

Four in every five respondents stated that visible demand was a key enabler to any growth in UK fabrication capacity. The UK government's commitment to a CCUS and hydrogen roadmap included in the UK Energy Security Strategy 2022 will support this.

- Track 1 clusters are beginning their market engagement processes which will provide direct visibility of these projects.

Skills are one of the highest barriers to capacity increase.

A number of respondents also pointed to foreign positive investment and the effect this has had on the competitiveness of the UK market, specifically in terms of materials fabricated and supplied from Asia.

As would be expected, a significant proportion of companies surveyed highlighted the need for an appropriate return on investment, which we view in the context of the investment requirement above and connected to concerns on access to competitive steel costs and productivity, barriers highlighted in the previous section.

Government support 'a factor in increasing capacity.'

The survey responses indicate a requirement for support and certainty e.g., through government support and formal UK content policy. This is consistent with the conclusions above and the report's proposed actions concerning targeted support and supply chain mechanisms.

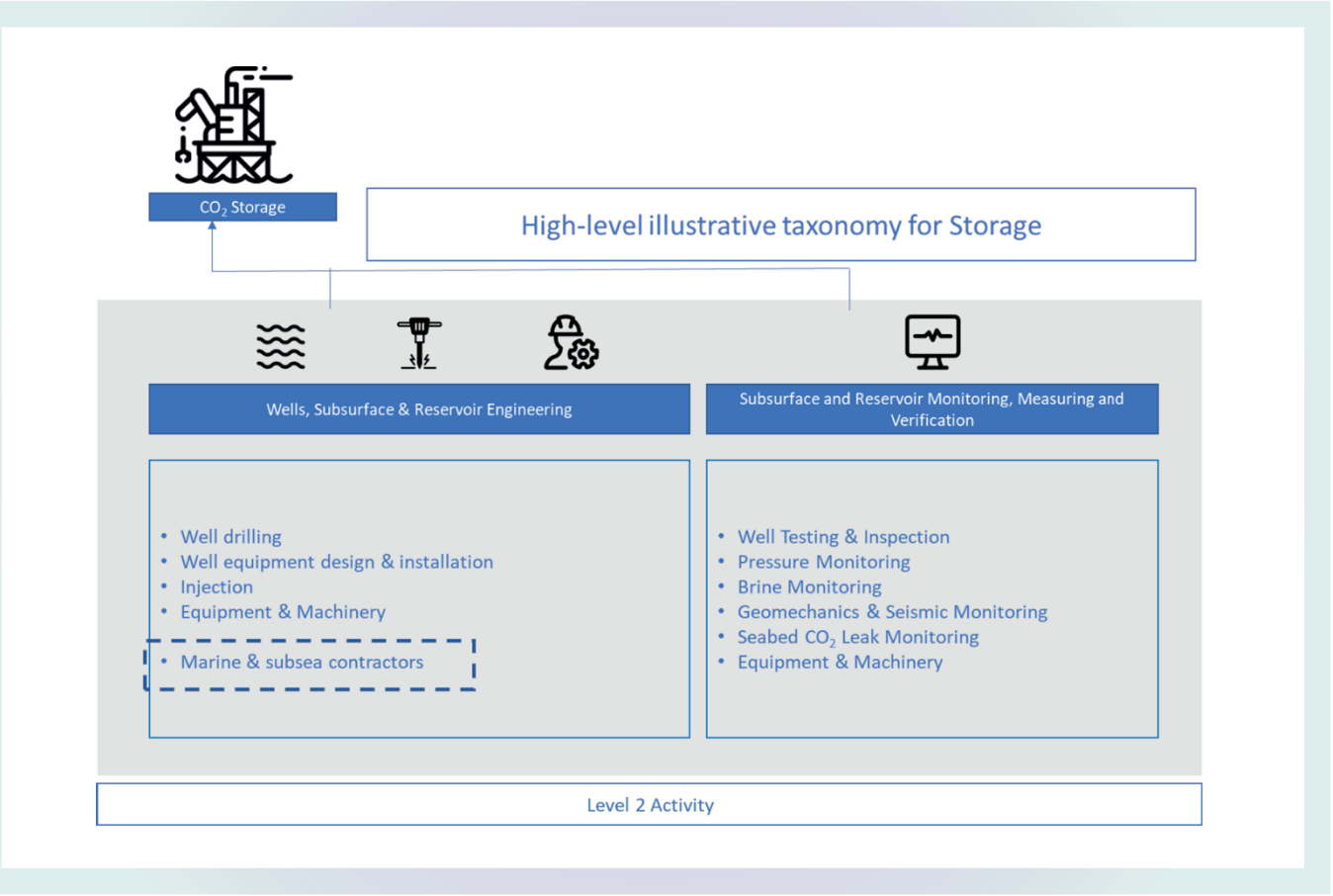
UK content is achievable.

Almost half the respondents strongly agreed with this statement, while no respondent selected 'strongly disagree' or 'somewhat disagree'. This is encouraging, but our conclusion from the above is that demand visibility will not be enough and that there are barriers to investment and expansion. Further assessment is needed to determine whether this is a viable supply chain opportunity and what support would be needed for the UK to respond to this opportunity.

Deep dive 2 : subsurface storage infrastructure

Introduction and Contextualisation

High-level illustrative taxonomy for storage, well services, and engineering was chosen as a deep dive.



Percentage of HQ location of survey respondents

Headquarter Locations	
Scotland	68%
Northeast England	12%
Midlands	12%
Southeast England	8%

The illustrative taxonomy for storage assumes CO_2 storage has already been identified and assessed. Any new CO_2 storage sites would require geological assessment. While this has not been assessed as its own supply chain area, the skills and experience are similar to those in subsurface and reservoir MMV which has been assessed and can be found in Section 6.4.

The strength and heritage of the UK oil and gas industry is a potential source of competitive advantage in CO_2 transport and storage. The UK could become a global leader in offshore sequestration. For many oil and gas firms, CCS appears to be a natural transition, pivoting the existing supply chain towards CCS, to provide the UK will the knowledge base, skills sets, and experience needed to build a capable sector here in the UK. Some of these skills can be exported.

To test this hypothesis, primary data via a 'deep dive' was collated through a survey. The survey was sent to known offshore developers and associated suppliers to understand capability, capacity, barriers and levers to increase capacity.

There has not been a validation process for the survey responses so the results below should be read in the context of the full report.

Answers we sought from targeted stakeholder engagement and survey

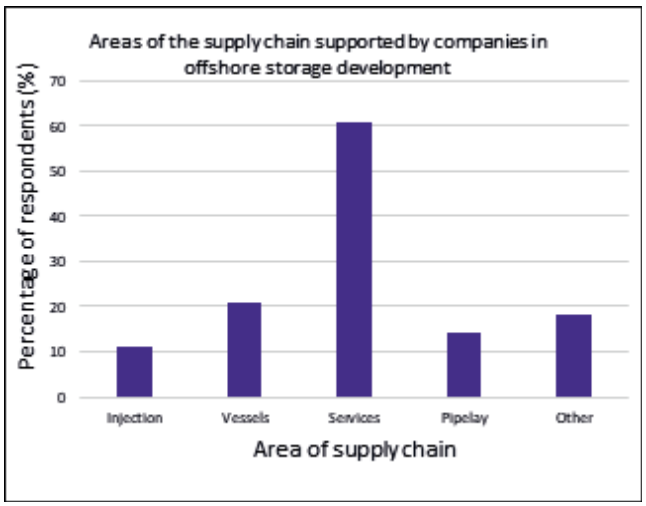
- The capability and capacity to store CO_2 offshore currently and what are the requirements to meet the future demand for offshore CCS storage in the UK.
- The capacity within the supply chain to perform all stages of the storage process.
- How to achieve the target of 50% UK content and 30% UK technology.

Summary survey findings

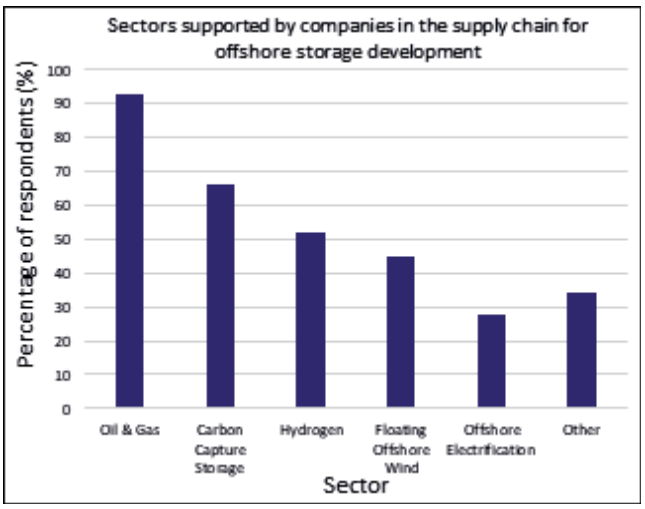
The oil and gas supply chain has the ability to support CCS requirements and is already pivoting to this sector.

Figures below reflect the introductory questions and confirm that survey respondents had capabilities relevant to this survey. The capability exists in supporting the necessary offshore development for CCS, most survey respondents support the oil and gas sector (93%), and a high number (67%) already support CCS projects, demonstrating that the supply chain is pivoting to the emerging CCS requirements.

Sectors supported by companies in the supply chain for offshore storage development. Most respondents are still active in the oil and gas sector (93%). Other sectors from respondents included fixed offshore wind, nuclear, grid & power engineering.



Areas of the supply chain supported by companies in offshore storage development. Other areas from respondents includedc, specialist technical engineering, production operations and audit.



The use of current assets and experience for CCS was rated as strong.

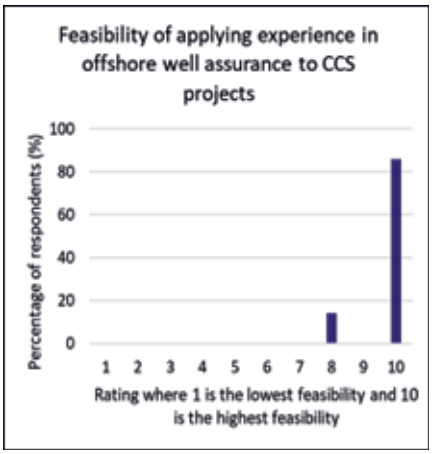
Most respondents rated the practicality at 9 or 10, suggesting that the supply chain for offshore storage development is ready to move into the CCS market as seen in the graphs opposite.

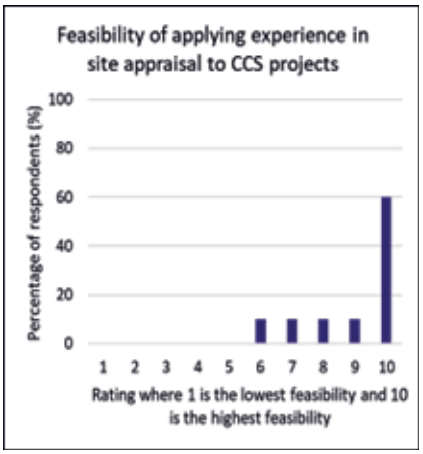
Respondents indicated relative ease of pivoting into the CCS market.

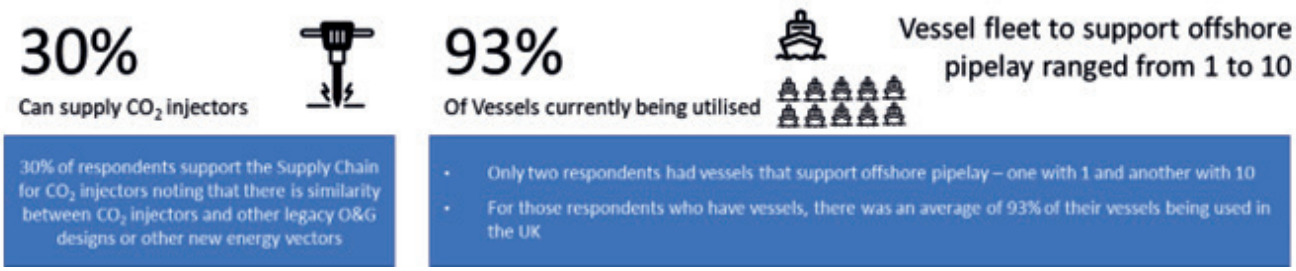
- 56% of the supply chain saw no barriers in repurposing assets for CCS. However, for those that did, common barriers identified were confidence in demand and government policy (is it an actual barrier or perceived risk?) concerning repurposing existing onshore assets for use in CCS involvement. Survey responses also showed that some companies feel their assets are best used in oil and gas production and there is not enough economic incentive for them to repurpose them.

Most respondents stated that they would require limited or no investment.

Indication of feasibility rating by companies in applying experience in offshore well assurance, site appraisal, and well drilling to CCS projects.







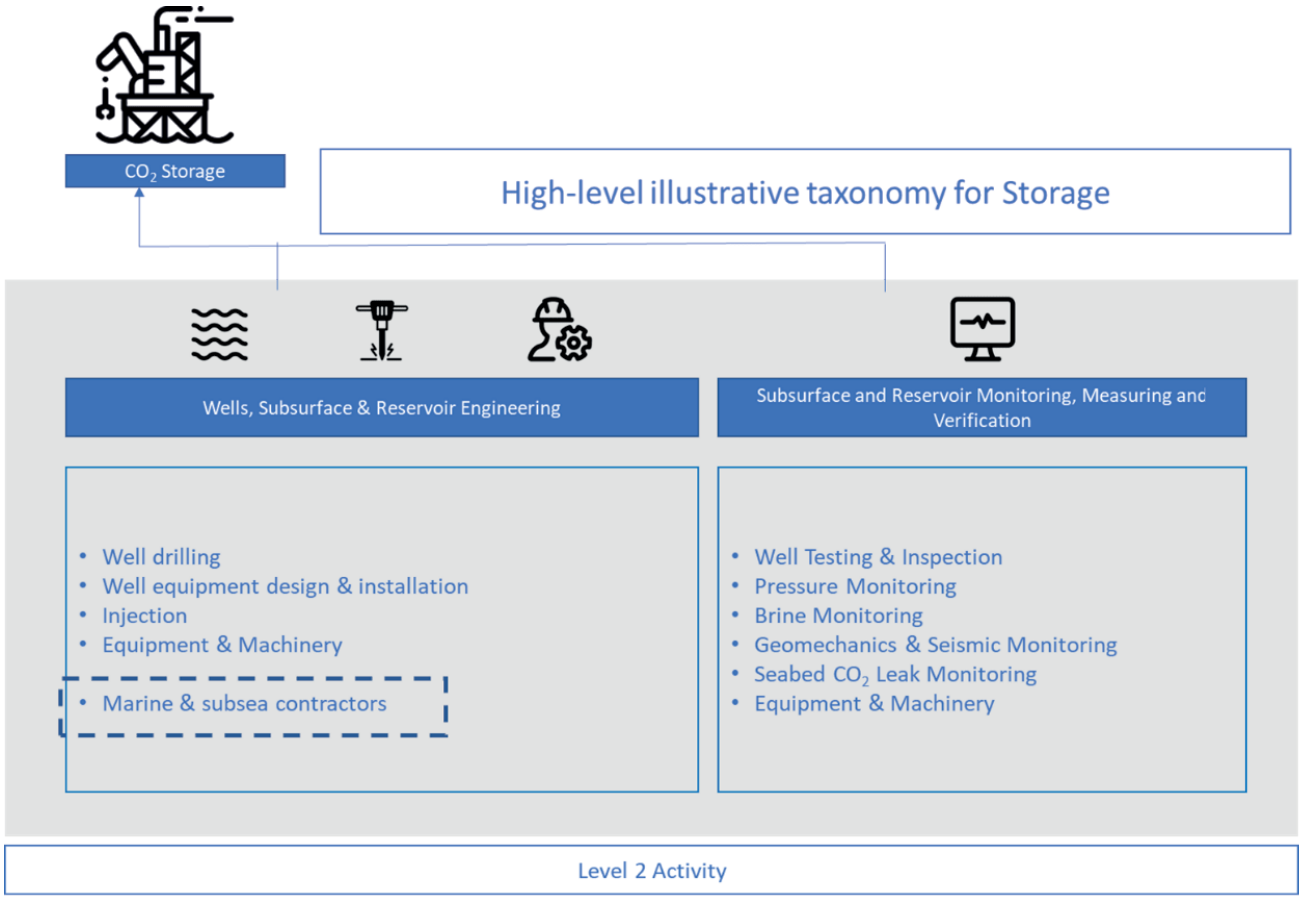
This would appear to be an area where the existing oil & gas supply chain is broadly well placed to meet current and prospective CCUS demands without additional capital investment suggesting that they are ready to enter the CCS market or are already active within it, a minority of respondents stated that they would require some expenditure. These respondents were involved with engineering and maintenance services and oil and gas production, suggesting that companies within this area of the supply chain may need more investment than companies involved in other areas.

UK content seen as achievable.

In general, respondents were confident that their current operations and supply chain support the 50% local content and 30% locally sourced technology targets. 41% of respondents strongly agreed that UK content was achievable, while no respondent selected 'somewhat disagree' and only 6% selected 'strongly disagree'.

Deep dive 3: Well services & engineering
Introduction, reflections and context

High-level illustrative taxonomy for storage, offshore storage development was chosen as a deep dive



Percentage of HQ location of survey respondents

Headquarter Locations	
Scotland	43%
Northwest England	25%
Northeast England	1%
Midlands	7%
Southeast England	13%

The well services and engineering deep-dive was chosen because of the large read across to the existing oil and gas sector and the ongoing opportunity that a successful CCS sector will create for the UK supply chain. Specialist subsurface knowledge and experience are critical to both the success of the sector and the public perception of risk. It will be critical to minimise leakage and ensure the stability of wells, and a critical factor in ensuring permanence which will contribute to the UK's NDCs, and any private company offsets/removals. Expertise in this area is required thought the entire development project value chain from initial concept screening and feasibility, right through to operational troubleshooting and improvement/optimisation studies.

There has not been a validation process for the survey responses and so the results presented below should be read in the context of the full report.

Answers sought from targeted stakeholder engagement and survey

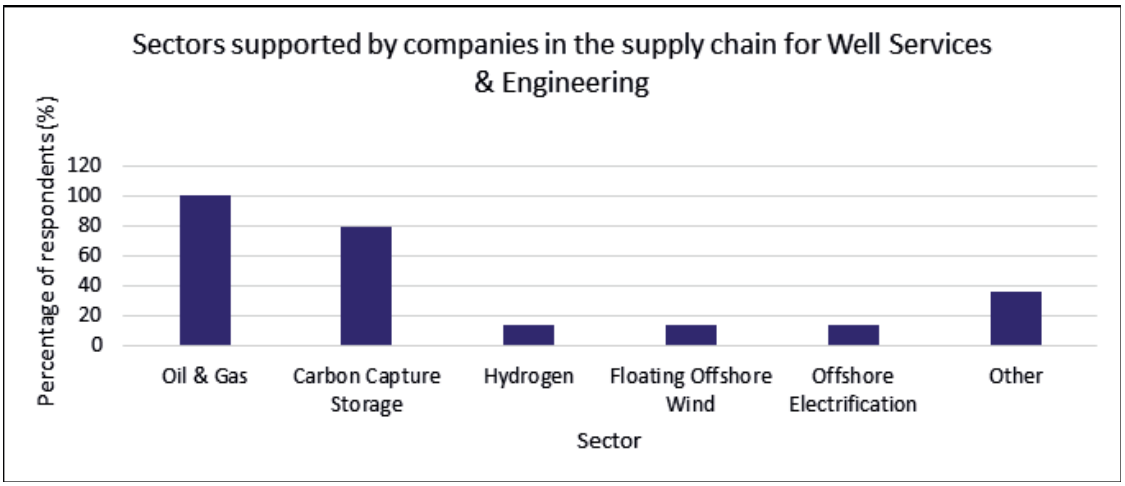
- The UK's capability for wells services and engineering
- The capacity to meet CCS demand
- The levers and barriers to increasing capacity
- Achievability of UK content targets

Summary of findings

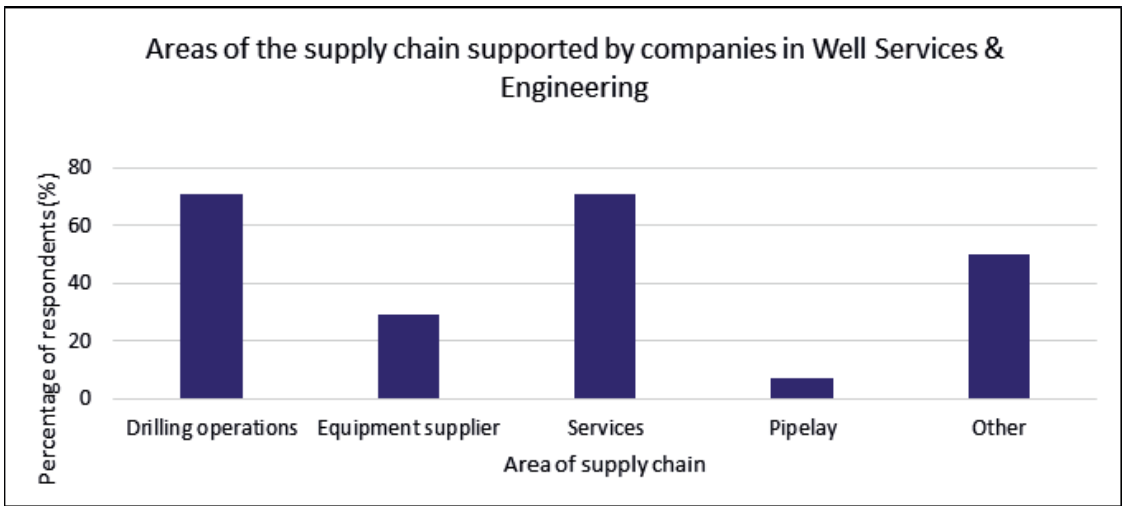
The oil and gas supply chain has the ability to support CCS requirements and in many cases is already doing so.

Figures here reflect the introductory questions and confirm that survey respondents have capabilities relevant to this survey. Oil and gas production is where most synergies were found: all respondents said they are already active in the oil and gas sector and four out of five said they are already active in the CCS market.

Sectors supported by companies in the supply chain for well services and engineering. All respondents are still active in the oil and gas sector (100%). Other sectors from respondents included; Gas storage (14%), Petrochemical (7%), and Geothermal (14%).



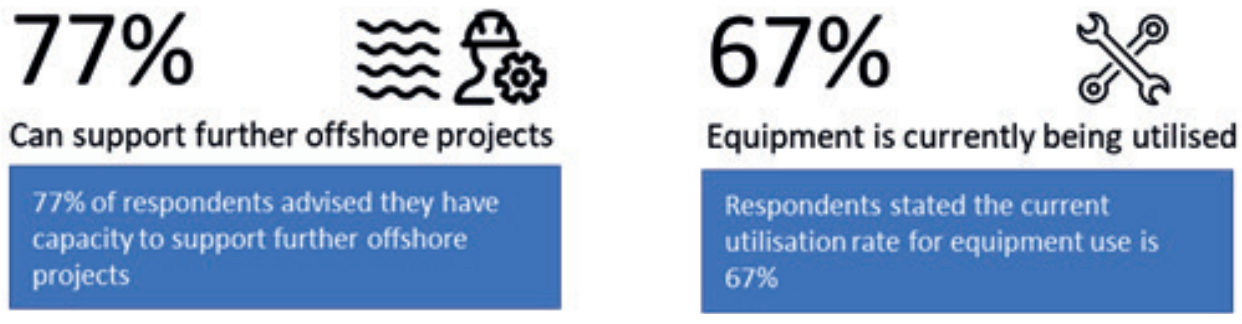
Areas of the supply chain supported by companies in well aervices and engineering. Other areas from respondents include feasibility studies, CCUS project engineering, preservation within the oil and gas industry, independent studies, well/pipeline operator, abandonment, and loss of control reviews for the insurance industry.



Figures on these pages indicate firms have a high degree of confidence in applying their experience and assets to CCS projects

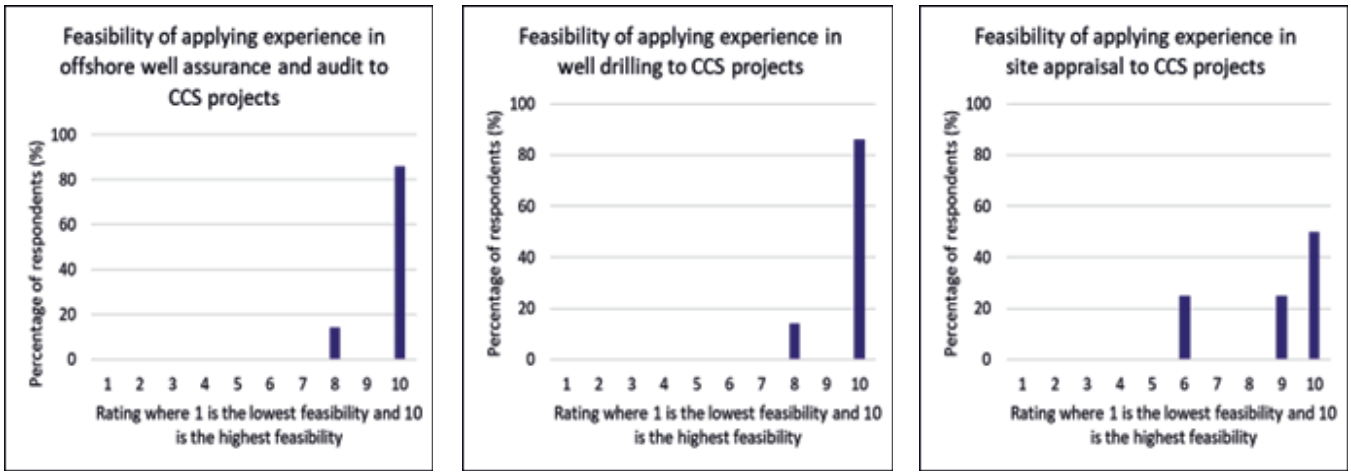
For firms that are already active in well services and engineering, there was a strong response to the feasibility of doing the same services for the CCS sector, with over 70% of respondents scoring it 8, 9, or 10/10 in this category.

Survey results indicate firms can support further offshore projects with equipment availability

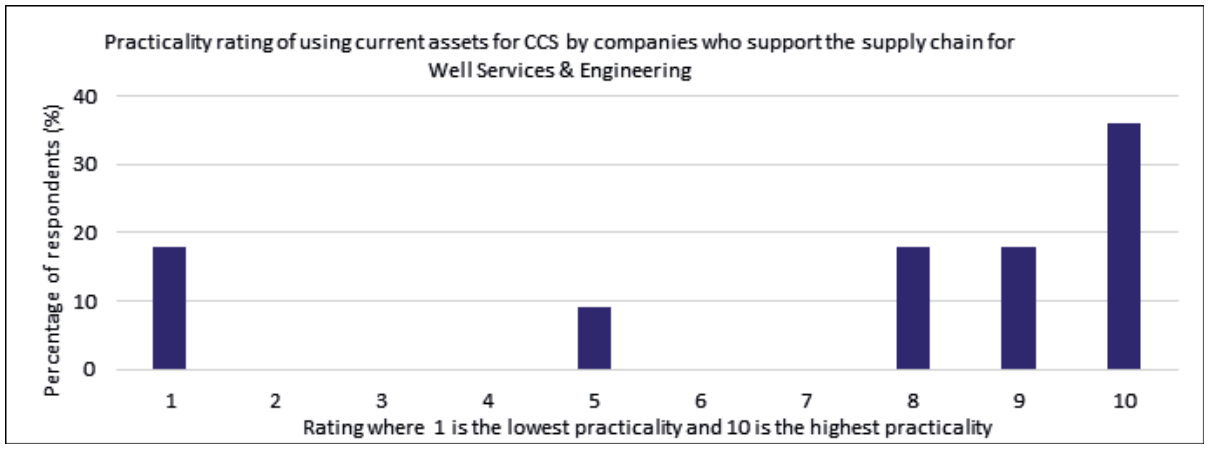


The statistics regarding utilisation rate and capacity reflect an ability to deploy assets on further projects. Notably, in the survey, one respondent called out that 'we are seeking to diversify projects for increased utilisation as part of involvement in the energy transition'.

Feasibility of applying experience in offshore well assurance and audit, well drilling, and site appraisal to CCS projects. Rating where 1 is the lowest feasibility and 10 is the highest feasibility



Perceived practicality of using current assets for CCS by companies who support the supply chain for Well Services & Engineering. On average, respondents rated the practicality of using their current assets for CCS at 7.



Low marginal cost of additional capacity

As with subsurface equipment this would appear to be an area where the existing oil and gas supply chain is positively positioned to meet evolving CCUS requirements. Based on the current visible pipeline of opportunity, little or no capital investment is needed for respondents to enter the CCUS market. Instead, potential concerns were raised that the opportunities afforded by oil and gas may be prioritised and absorb available capital spending over CCUS, which is regarded as an inferior business at time of writing.

Demand visibility is a key factor in increasing capacity

When asked what enabling factors would allow for capacity increase survey respondents pointed to several factors, demand visibility being a key one.

Select survey respondent response to UK content question 'Enabling factors and barriers to the increase of current capacity to provide equipment or services to support the CCS market space'

'Clear timeline, client commitment, funding'

'Our existing assets are ready to support CCS projects. Visibility of upcoming projects would help us'

UK content seen as achievable.

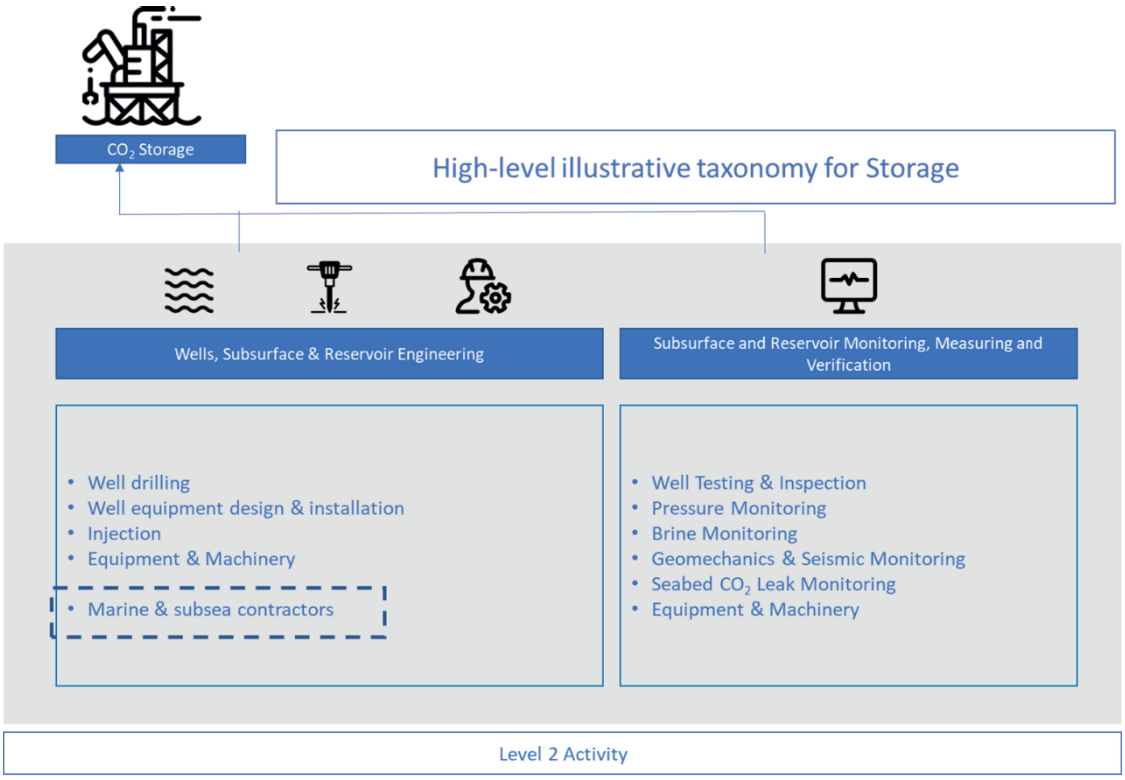
Half of the respondents strongly agreed that their operations support the NSTD local content targets, and respondents, in general, were confident that these would be achieved.

- An example of a respondent who already meets local content targets wrote: 'We utilise up to 70% local resources to support ongoing operations and supply chain and have historically developed new innovative and cutting-edge technology locally within Scotland for previous oil and gas projects.'
- Another responder noted: 'We are a UK based entity, and all UK operations are planned and managed out of the Aberdeen office by locally based personnel. Supply chain support is also awarded on a regional basis, and it should be feasible to achieve more than 30% local content by cost. It would perhaps be more challenging to achieve 'locally sourced technology. However this could be introduced as tender evaluation criteria and therefore ensure proper focus when awarding subcontracts.

Deep dive 4: geomechanics, permeability, MMV and seismic monitoring

Introduction and contextualisation

High-level illustrative taxonomy for storage, geomechanics, permeability, MMV, and seismic monitoring was chosen as a deep dive.



Percentage of HQ location of survey respondents

Headquarter ocations	
Scotland	55%
Southeast England	27%
Wales	18%

UK CO_2 storage has been identified as a major opportunity for the UK thanks to its substantial geological potential. The services required for the ongoing monitoring of CO_2 storage locations (geomechanics, permeability, MMV, and seismic monitoring) were chosen as a deep-dive topic because of the ability to utilise pre-existing skillsets from the oil and gas sector and to test the insights gathered from stakeholder interviews.

Monitoring is required across the full project lifecycle and so it is critically important that there is a solid UK supply chain to support the CCS sector as it develops. The high-end expertise required for these services makes this a distinctive capability, one where the the UK could become an exporter. MMV assurance will also be critical in maintaining a solid public perception of the CCS sector as leakage remains a significant concern.

There has not been a validation process for the survey responses and so the results presented below should be read in the context of the full report.

Answers sought from targeted stakeholder engagement and survey

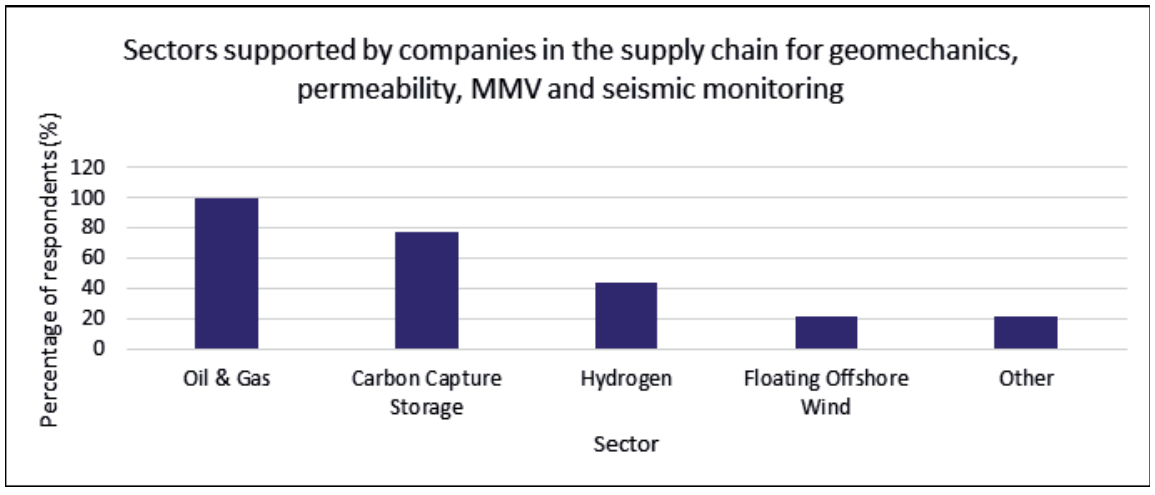
- The UK's capability for geomechanics, permeability, MMV, and seismic monitoring
- Capacity to meet CCS demand
- Levers and barriers to increasing capacity
- Achievability of 50% UK content and 30% UK technology be met

Summary of findings

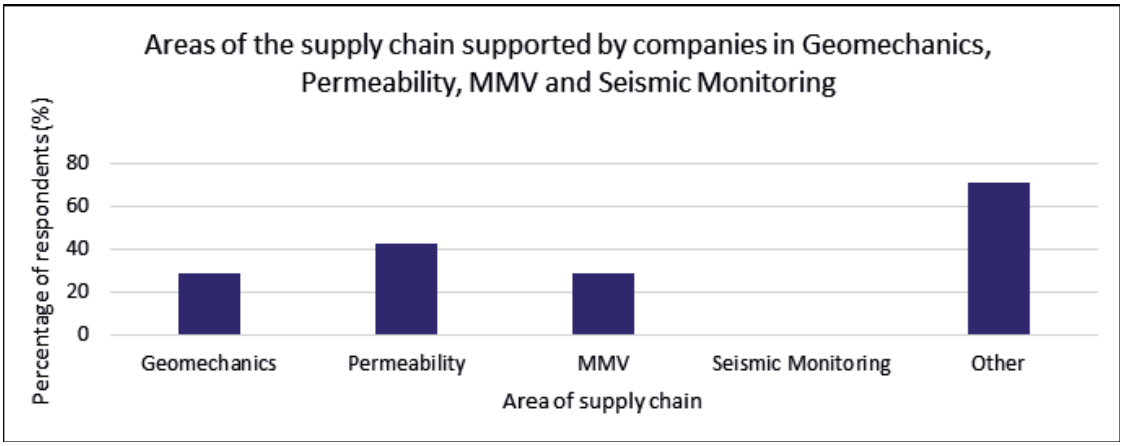
The oil and gas supply chain can meet CCS needs

The figures that follow reflect the introductory questions and confirm that survey respondents have capabilities relevant to this survey. There are existing synergies with oil and gas and four fifths are already supporting CCS and some other energy opportunities indicating supply chain capabilities for these services are strong, owing to their applications in reservoirs used in the oil and gas industry.

Sectors supported by companies in the supply chain for geomechanics, permeability, MMV, and seismic monitoring. All respondents are still active in the oil and gas sector (100%). Other sectors from respondents included; helium, municipal water, fixed offshore wind.



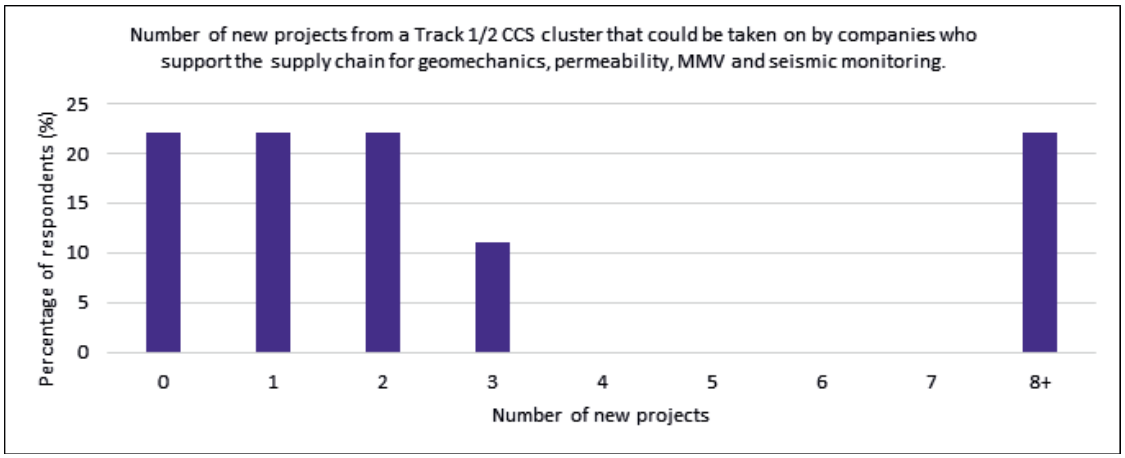
Areas of the supply chain supported by companies in geomechanics, permeability, MMV and seismic monitoring. Other areas included TIC services, flow meter calibration, plug and a bandonment, zonal isolation and sustained casing pressure, pipeline cleaning and dewatering, corrosion protection, subsea ballast/buoyancy.



Respondents provided further detail on capacity.

- **Specific capacity was indicated in flow meter calibration facilities.** This is currently under-utilised and can be used for CCS (as well as hydrogen projects). Additionally, there is confirmation from the supply chain that more flow meter calibration facilities are being constructed, commissioned, and designed, to support future capacity.
- **Opportunity indicted in seismic data collection.** Ocean bottom seismometers (OBS) can acquire passive seismic data. The survey indicated that companies within this aspect of the supply chain have resources on standby that are under-utilised and can be deployed when necessary.

Number of new projects from a Track 1/2 CCS cluster that could be taken on and monitored on an ongoing basis by companies who support the supply chain for geomechanics, permeability, MMV and seismic monitoring.



Demand visibility is a key action in increasing capacity.

When asked what enabling factors would allow for capacity increase survey respondents pointed to several factors, demand visibility being a key one.

Select survey respondent response to UK content question: 'What are the enablers and barriers to more capacity to provide equipment or services to support the CCS market space?'

'Visibility of project needs, and commercial development opportunity'

Sufficient long-term projects to maintain business focus and enhance our expertise focussed on CCS, on the risks, uncertainties, and mitigation technologies

'Increased certainty that CCS will happen'

Some limited investment may be needed to increase capacity.

Survey participants regard this sector as an area where capital investment is required across the board to meet the challenges and opportunities presented by CCUS. Financing was identified as necessary across a broad spectrum, from equipment, technology, and skills, to assets and infrastructure. While investments of smaller magnitudes relate to technology development and enhanced service provision, the larger investment amounts relate to the acquisition of specialist equipment and facilities such as flow meter calibration for gas and liquefied CO_2.

UK content targets 'achievable.'

In general, respondents were confident that their current operations and supply chain support the targets for local content and technology. Two thirds of respondents either strongly agreed or somewhat agreed that their current operations and supply chain support them.

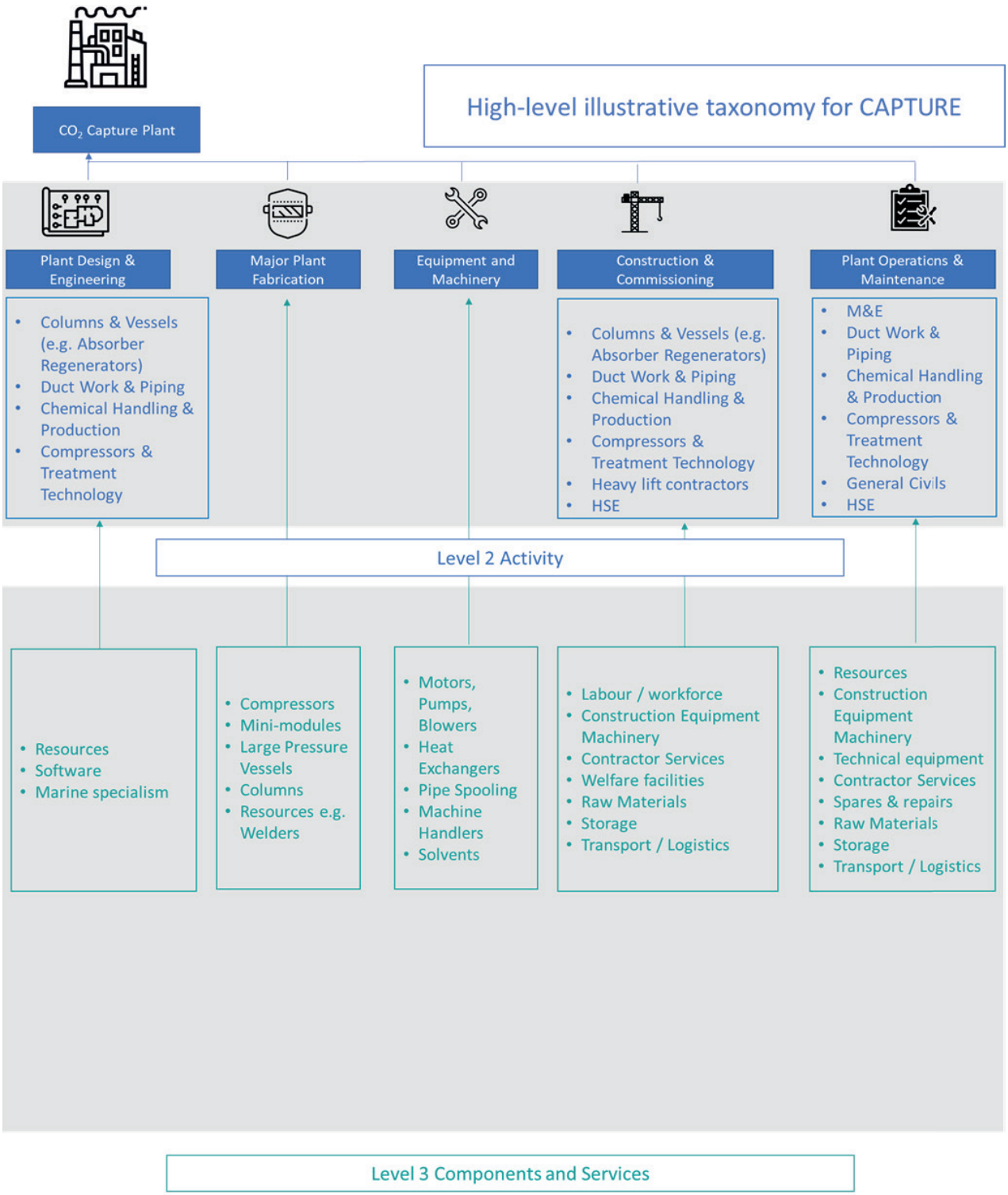
Survey response to UK content question.

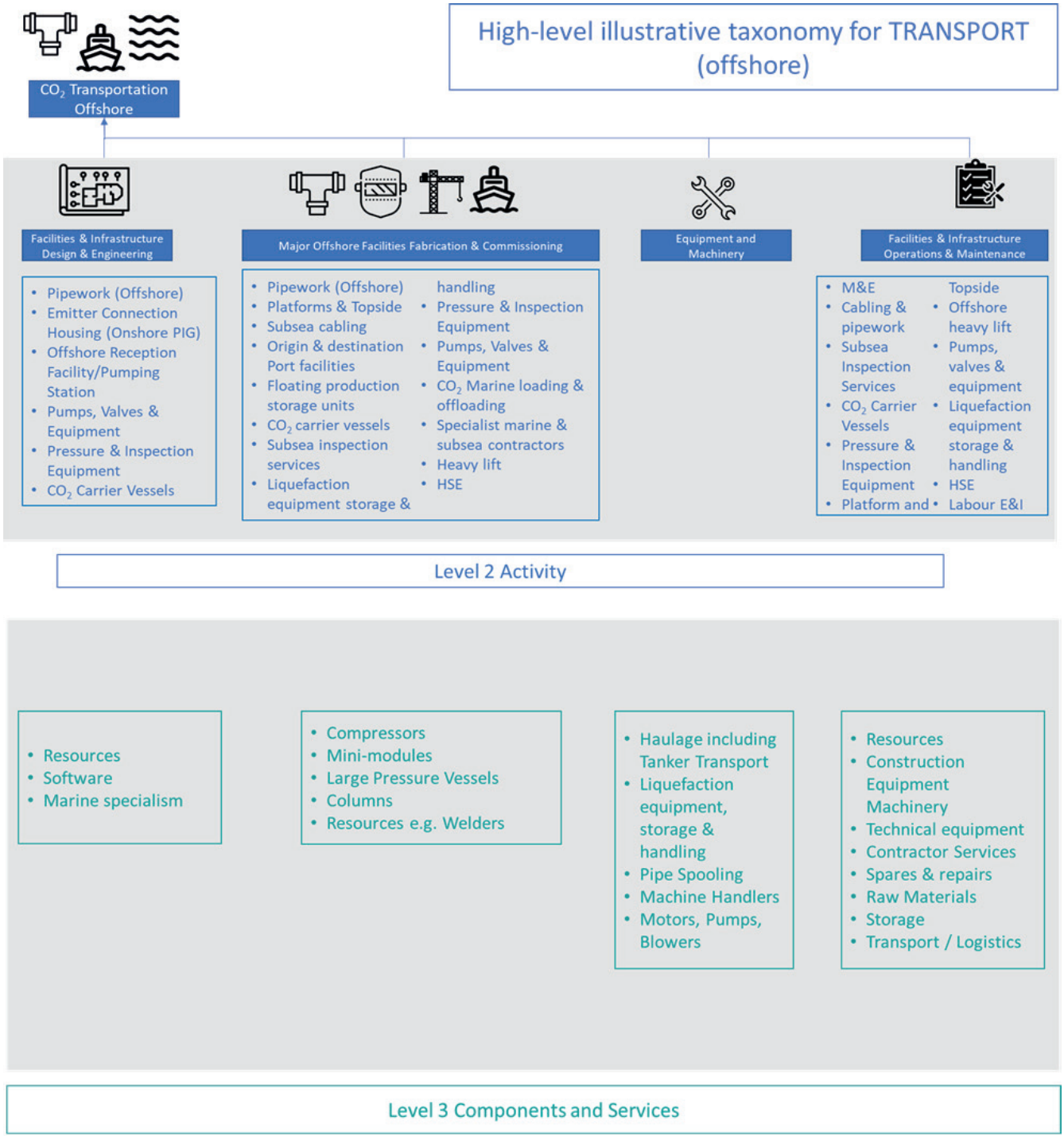
'Our services are 100% UK based but rely on software provision from both international and local providers. We would prefer to work with local providers to develop specific CCS targeted technologies and software to address the current uncertainties in CCS projects, and to target MMV expenditure towards the key and critical project uncertainties'

Appendix B: Glossary and abbreviations

Abbreviation	Definition
BEIS	Department for Business, Energy & Industrial Strategy
CCS	Carbon Capture & Storage
CIF	Carbon Capture & Storage Infrastructure Fund
CO_2	Carbon Dioxide
DACC	Direct Air Carbon Capture
EPC	Engineering, procurement & construction
GHG	Greenhouse Gas
KPIs	Key Performance Indicators
LNG	Liquefied Natural Gas
LPG	Liquid Petroleum Gas
mt	Metric tons
mn mt(/yr)	Millions of metric tons(/year)
NSTD	North Sea Transition Deal
NSTF	North Sea Transition Forum
OEUK	Offshore Energies UK
O&G	Oil & gas
O&M	Operations & maintenance
R&D	Research and development
T&S	Transport & storage
TWh	TeraWatt-hours
SME	Small to medium enterprise
UKCS	UK continental shelf

Appendix C: Taxonomy




High-level illustrative taxonomy for TRANSPORT (offshore)
CO_2 Transportation Offshore
Facilities & Infrastructure Design & Engineering
• Pipework (Offshore)
• Emitter Connection Housing (Onshore PIG)
• Offshore Reception Facility/Pumping Station
• Pumps, Valves & Equipment
• Pressure & Inspection Equipment
• CO_2 Carrier Vessels
Major Offshore Facilities Fabrication & Commissioning
• Pipework (Offshore)
• Platforms & Topside
• Subsea cabling
• Origin & destination Port facilities
• Floating production storage units
• CO_2 carrier vessels
• Subsea inspection services
• Liquefaction equipment storage & handling
• Pressure & Inspection Equipment
• Pumps, Valves & Equipment
• CO_2 Marine loading & offloading
• Specialist marine & subsea contractors
• Heavy lift
• HSE
Equipment and Machinery
Facilities & Infrastructure Operations & Maintenance
• M&E
• Cabling & pipework
• Subsea Inspection Services
• CO_2 Carrier Vessels
• Pressure & Inspection Equipment
• Platform and Topside
• Offshore heavy lift
• Pumps, valves & equipment
• Liquefaction equipment storage & handling
• HSE
• Labour E&I
Level 2 Activity
• Resources
• Software
• Marine specialism
• Compressors
• Mini-modules
• Large Pressure Vessels
• Columns
• Resources e.g. Welders
• Haulage including Tanker Transport
• Liquefaction equipment, storage & handling
• Pipe Spooling
• Machine Handlers
• Motors, Pumps, Blowers
• Resources
• Construction Equipment Machinery
• Technical equipment
• Contractor Services
• Spares & repairs
• Raw Materials
• Storage
• Transport / Logistics
Level 3 Components and Services

Appendix D: Methodology

The following high-level methodology was used to develop the findings set out in this report:

1. Desktop-based research

A wide-ranging and a representative number of sources were reviewed to form hypotheses on the UK supply chain's capability and capacity which could be tested with stakeholders currently working in the oil and gas industry, government, and other relevant areas. Existing research and data were used to extract and synthesise relevant CCS information to provide a rounded overview of CCS. A full list of sources reviewed for this report can be found in Appendix G.

2. Stakeholder engagement

In preparation for this report, engagement with trade bodies and associations was conducted across the offshore energy space (e.g., the Carbon Capture and Storage Association (CCSA), UK Hydrogen and Fuel Cell Association (HFCA), RenewablesUK). Further engagement was conducted with devolved administrations, namely the Welsh, Scottish & Northern Irish relevant bodies. Stakeholder interviews (approximately 30) were conducted with leaders across the energy industry who predominantly sat in Tier 1 supply chain firms. Questions covered:

- UK's ability to meet local content ambitions
- Notable gaps that exist at present within the energy supply chain
- What companies need to scale up solutions and create value for industry
- How firms have prioritised their business objectives to account for the energy transition
- Whether they consider technology innovation being driven from the UK or internationally, and what channel this is being driven from (academia, operators, consortia, supply chain, government)
- What their firm's top risks are in transitioning
- What key opportunities their firm sees over the next 5 years
- Any other points of note

3. Primary data gathering

Desktop analysis and stakeholder interviews provided the insight to determine the capability and capacity of Levels 1 -2 of the CCS Taxonomy. A select number of level 3 areas were selected to conduct 'deep dives' to provide primary data to support or challenge findings. The primary data was gathered through a targeted survey questionnaire via Qualtrics to evidence capability, capacity, and barriers and levers to increase capacity. Just over 200 survey responses were received. Key exceptions are listed below:

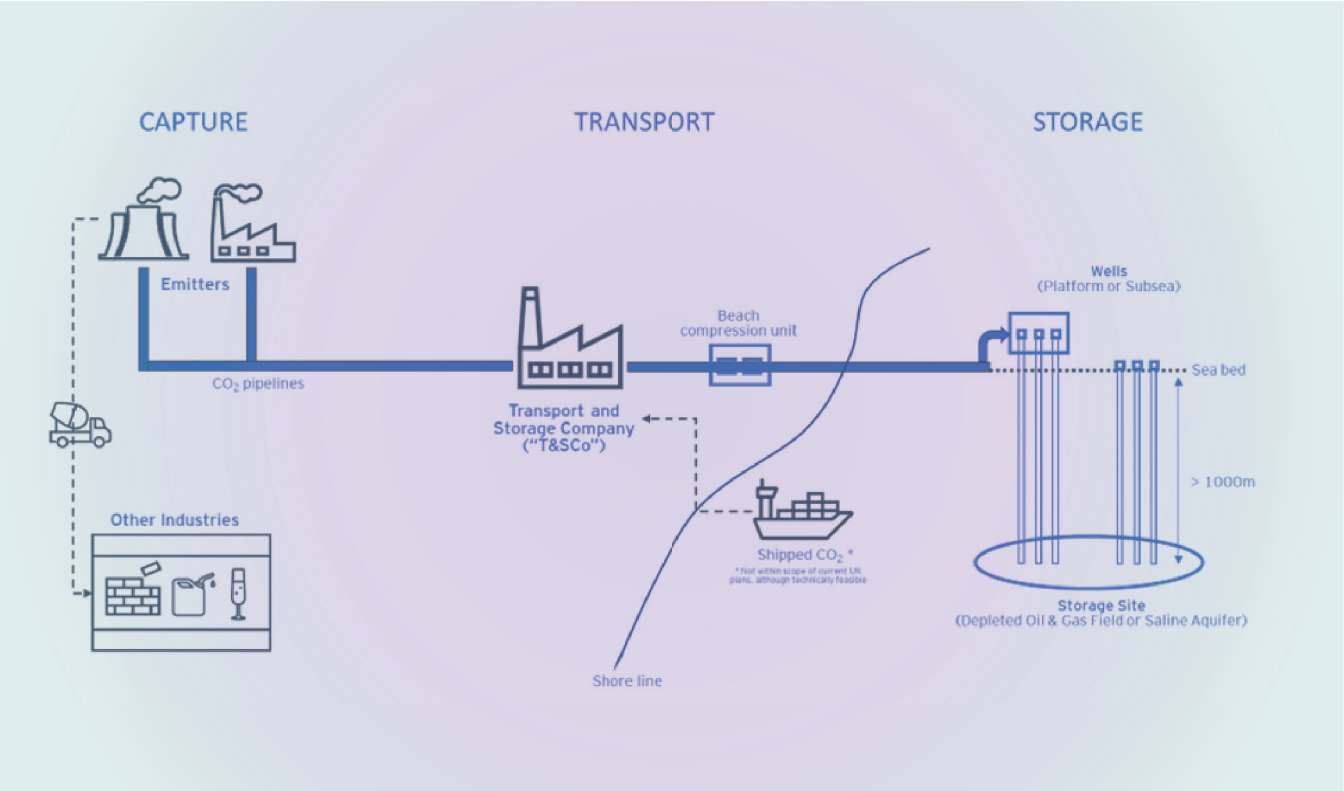
- The report is a supply chain focused document, and therefore it will not assess the various merits of different types of CCS. It is primarily being delivered on behalf of OEUK, acknowledging the need for the oil and gas industry to transition as the energy transition increases in speed and intensity.
- The report is not an assessment of the merits of the oil and gas industry's supply chain.
- The report is not endorsing the full-scale transition from the oil and gas industry to the CCS industry, as the need for the oil and gas industry as part of the hybrid energy industry moving forward is recognised.
- The survey and interviews are a snapshot and sample of parts supply chain at a moment in time (November 2021 – March 2022).
- The report is not a cost assessment of the different working parts of the supply chain.
- The report excludes the labour and skills element. It recognises that this is vital and confirms this line of work is being done by OPITO.

The list below identifies all the areas that were chosen as a deep dive and those that were not with some clarification for selection.

	Supply chain area	Associated Deep Dive	The rationale for choice or exception
Capture	Plant Design & Engineering	None	This area was not chosen as a deep dive as it is already well established and was not assessed as requiring deeper analysis.
	Major plant fabrication	Fabrication of columns, vessels, ductwork, piping and other components	
	Equipment/ machinery/design and manufacture	None	This area was not chosen for a deep dive as CCS technology development is being evaluated in a report by the Technology Leadership Board (TLB).
	Construction & commissioning	None	This area was not chosen for deep dive as the UK construction industry is already well established and thus capability is not an issue.
	Plant O&M	None	This area was not chosen as a deep dive as plant O&M is already well established, and the opportunity for these services to be monetised will be more apt in the late 2020s. O&M procurement is generally completed at the same time as procurement for construction & commissioning. This will secure resources earlier than operational dates removing them from the capacity pipeline.
Transport	On/offshore pipeline transport	None	This section was not chosen for a deep dive as this was not seen as a realistic opportunity area for the UK.
	Ship transport of CO_2	None	This topic was not chosen for a deep dive as there is no current capability for CO_2 tankers.
	Marine loading/ offloading	None	This topic was not chosen for a deep dive owing to the strong links to CO_2 shipping, which would require a deeper look at the overarching opportunity to the UK before succinctly exploring the supply chain elements.
Storage	Wells, subsurface and reservoir engineering	Offshore development	This area was not selected as a deep dive area due to the existing geology studies in offshore storage development, current UK focus is infrastructure build.
	Marine/subsea contractors	Offshore development	
	Subsurface and reservoir monitoring, measuring, and verification	Geomechanics, permeability, MMV, and seismic monitoring	

	Scale definition	
	Capability	**Value & accessibility of opportunity**
●	The UK can supply all the required capability.	There is a significant opportunity, readily accessible to the existing supply chain.
◕	The UK can supply most of the required capability.	There is a significant opportunity but some constraints or barriers to access.
◑	The UK has moderate coverage of the required capability.	There is a moderate opportunity with constraints or barriers to access.
◔	The UK has limited coverage of the required capability.	There is a limited opportunity with challenging constraints or barriers to access.
○	The UK has minimal coverage of the required capability.	There are prohibitive constraints of access limiting the value of the opportunity.

Appendix E: CCS global insights



CCS is an integrated chain of technologies and systems, consisting of Capture, Transportation, and Geological Storage of CO_2.

- **Capture:** : this element of the value chain separates CO_2 from other gases and can be achieved through various methods depending on the process requirements. Post-combustion capture is applied to industrial and power applications where the combustion of a hydrocarbon-containing element has taken place. Most applications of this technology today use amine-based absorptions systems. Pre-combustion capture is the separation of CO_2 before combustion, generally applied to natural gas sweetening and hydrogen production. An alternative method is Oxy-fuel combustion where oxygen is used for process combustion rather than air, which produces a clean exhaust gas of high-purity CO_2 and water vapour.

- **Transportation:** this involves the compression of the captured CO_2 into a dense, gaseous, or liquid phase, that enables transportation from the capture location to the storage facility. This can be achieved through pipelines, ships, or even rail/road tankers.

- **Storage:** this is where the CO_2 is injected into sub-surface formations, where the CO_2 disperses within pore space and is contained within the subsurface by impermeable sealing layers. Storage can occur onshore and offshore, either in depleted oil and gas formations, or saline aquifers.

European storage is expected to be mostly offshore as former gas reservoirs have already proven gas containment.

CCS: an opportunity for the oil and gas supply chain

The CCS sector is entering a period of global growth that is expected to be sustained as countries and economies drive for net-zero societal emissions. The IPCC scenarios require storing between 350 and 1,200 gigatons, at least 100 times more than today's installed capacity, by 2050 . The market valuation of the sector in 2020 was $1.9bn, projected to grow at a compound annual growth rate of 13.8%/yr . By 2050 growth is expected to exceed $100-120bn . ExxonMobil estimates that CCS could be a $2 trillion revenue opportunity by 2040 , which indicates the potential for growth. CCS represents an opportunity for organisations that have traditionally operated exclusively in oil and gas production and services to transition and continue utilising their skills and expertise in a new way, as well as develop new capabilities to support the CCS sector. Whether it be the process and chemical engineering expertise required in the capture plants, expertise in transporting liquid, gaseous and dense phase CO_2, or the offshore geology that stores CO_2, the oil and gas supply chain is critical to ensuring the CCS sector is successful.

It is estimated that about $375bn-650bn of global investment would be needed to meet the expected growth (~800mn mt/yr) in CCS deployment by 2030. According to the Global CCS Institute, there are currently 135 CCS projects in the project pipeline globally, and in the first nine months of 2021 alone, 71 projects were added[39].

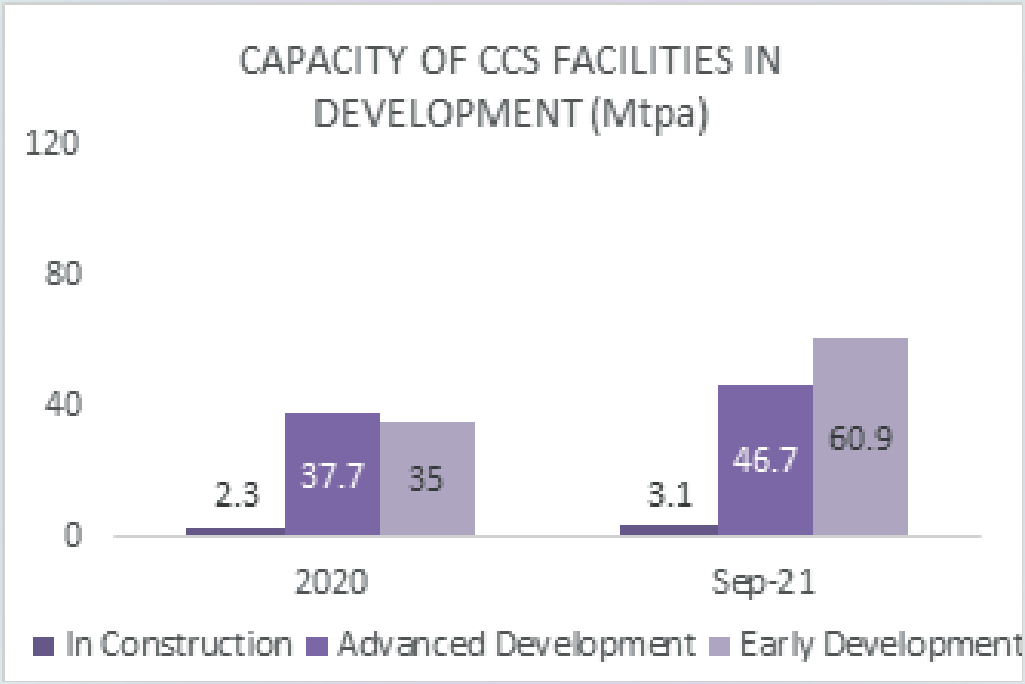
The global growth through 2020 into 2021 demonstrates that CCS is becoming more attractive to both policymakers and developers. Whilst there is a much lower proportion of projects currently in construction (compared with development), this will undoubtedly start to ramp up as policies and business models take projects towards final investment decision. The UK supply chain needs to mobilise quickly to be ready and able to deliver and capitalise on this growth.

Trends & insights

The oil and gas sector is extremely important to the success of the CCS industry, through its extensive subsurface knowledge and related capabilities which have been deploying CCS technology since the 1970s. This expertise will continue to support high-value jobs that will support the transition to a safe and cost-effective low-carbon future.

The oil and gas supply chain has an opportunity to support the entire CCS value chain of capture, transport and storage. Capture and transport will be mainly focused on engineering and construction through the design and fabrication of critical components such as towers, vessels, and pipework, mimicking oil and gas and refining today. Storage requires the same offshore and subsurface skill sets deployed on oil and gas assets, so the skills and technologies are transferable. There are some differences between storing CO_2 and extracting oil and gas such as chemistry and material selection.

Collaboration has been evident in the oil and gas sector for decades, with joint ventures and common



Oil & Gas sector to dominate the CCS market

CCS presents the oil and gas sector with a raft of opportunites to decarbonise assets; delay decomissioning; enhance oil recovery yields; and re-use legacy capabilities to support other sectors in permanently storing CO_2 emissions

In 2019, oil and gas-associated companies dominated the CCS market with over 80% share

Manufacturing & modularisation

Component manufacturing towards the deployment of CCS has yet to be fully standardised, presenting opportunities for early movers

Modular plants are under early phase development for set sizes/scales of plant, optimising production, effort and time,

Collaborations among industry players for large scale projects

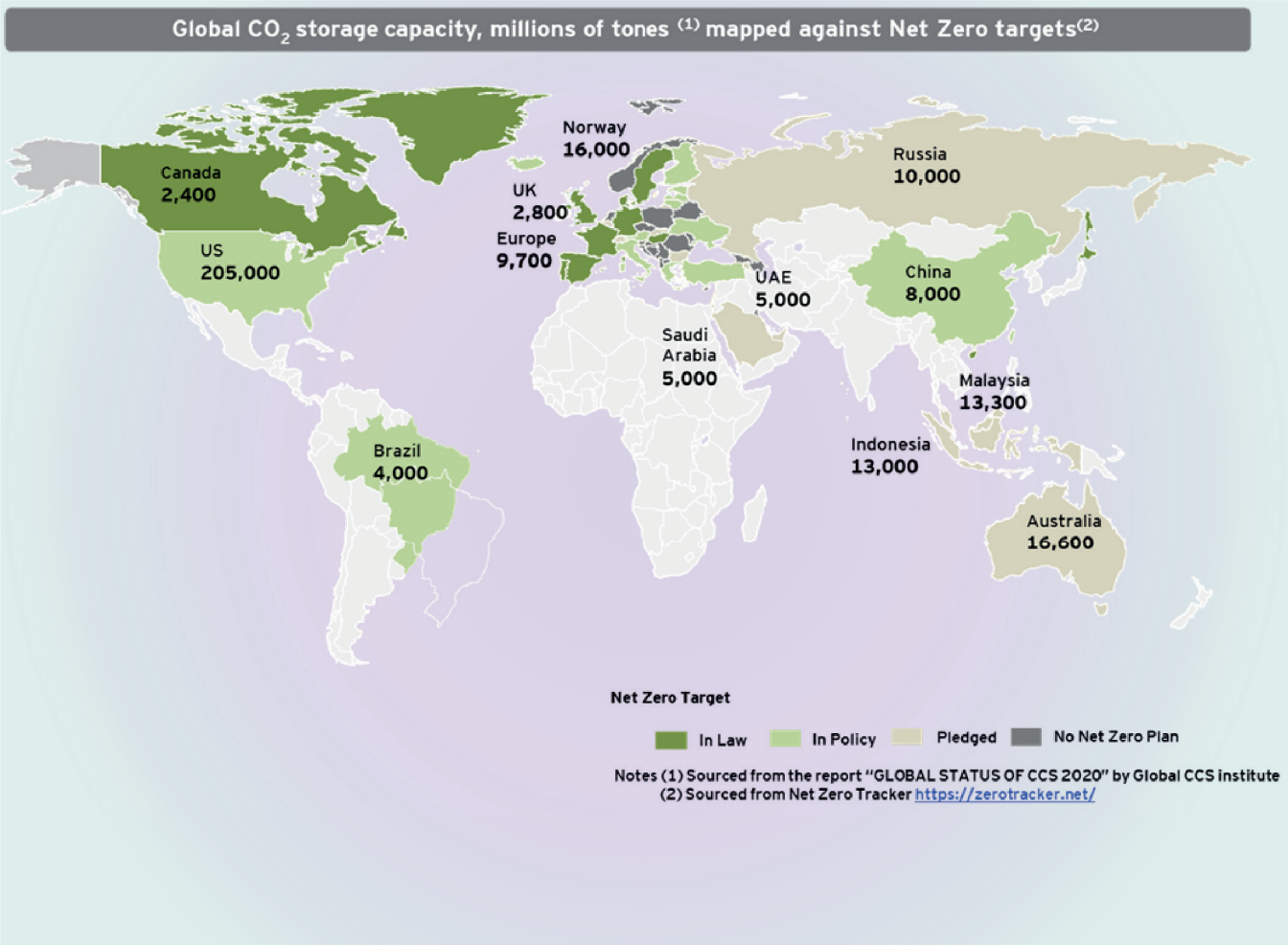
Collaboration among industry players is already matching legacy oil and gas approaches of sharing risk and reward

Northern Lights in Norway as an example is a collaboration between Shell, Equinor & Total

approaches to projects to maximise project economics and share risk as examples. The CCS sector is already benefiting from this approach which can be seen via the development of shared infrastructure and CCS clusters/hubs

Global CO_2 storage capacity & demand

The overall technical storage capacity for storing CO_2 underground worldwide is still to be fully determined, but estimates based on known geology and R&D are significant even in the context of the quantities of carbon that will require to be sequestered and further demonstrate the potential of CCS as a key route to easing climate change. Currently, only a few countries are using their available capacity to capture and store CO_2, with the US having the highest number of operational CCS facilities. A high number of today's active projects are using CO_2 for enhanced oil recovery.



The graphic above demonstrates the known CO_2 storage capacity from countries that have proposed or enacted net zero strategies. The capacity values indicated are purely based on depleted oil and gas reservoirs where more research is certain. Geological storage resources within saline formations are hundreds of times larger.

Global operational CCS projects

Analysis has been carried out on operational CCS projects that the UK can look to for lessons learned and to further indicate the supply chain opportunity. Owing to the scale, risk, and investment required, large multinational companies were selected to provide most of the high-value elements through consortium lead approaches. The below table lists the publicly available data on each project indicating that capex, EPC, technology, equipment suppliers, and fabrication details were available. This provides a succinct overview linked across to the taxonomy.

ing of where manufacturers are pushing their equipment envelope (size, performance, temperatures, pressures, environment, materials, etc.) and either select a more proven vendor (if one exists), or drill into the vendor's plan to address, and/or contract for more robust performance guarantees or warranties.

Project	Boundary Dam	Quest	Gorgon	Petra Nova
Operator	SaskPower	Shell Canada	Chevron	NRG
Location	Canada	Canada	Australia	USA
Cost	**$1.5bn** $800mn for the CCS process and $500mn for retrofit cost	**$1.35bn** Built ahead of schedule and under budget	**$2.3bn**	**$1bn**
Capture technology	Post-combustion amine	ADIP-X amine Shell patent	Not publicly available	Post-combustion KM-CDR amine
EPC	SNC Lavalin and Cansolv Technologies Limited Stantec for engineering consultancy	Fluor Corporation	Kellogg Joint Venture Group (KJVG) included KBR JGC Clough and Hatch CB&I Kentz joint venture for mechanical, electrical, and instrumentation	Consortium of; Mitsubishi Heavy Industries America & The Industrial Company Sargent & Lundy engineering services and detailed design of ductwork
Equipment providers	Hitachi supplied a steam turbine Babcock and Wilcox supplied the boiler in Unit 3	Not publicly available	GE supplied CO_2 injection components ABLE Instruments & Controls supply flowmeters Subsea 7 for the transportation and installation of subsea umbilical and structures McDermott for mechanical, piping, electrical, instrumentation, and commissioning of three LNG trains, and others include Monadelphous, Howard Porter, Thiess, HLV Jumbo Jubilee, Leighton and Saipem, Leighton, CBI Contractors, and Chinese Offshore Oil Engineering Company	Heat recovery steam generator from Nooter/ Eriksen Cooling tower from SPX Dehydrator from Tryer Structural steel from Cives Steel Co
Fabrication provider	Not publicly available	KBR Canada	Hyundai Heavy Industries; fabricated liquefaction train modules	Not publicly available
CO_2 storage	Cenovus Energy of Calgary purchases the 1mn mt/yr of CO_2 capture at Boundary Dam for Enhanced Oil Recovery projects operated by Cenovus operated near Weyburn	Underground storage, 80 km from the facility transported through an underground pipeline	Onshore pipelines stored in sandstone reservoirs	The captured CO_2 is compressed, dried, and transported through a 100-km pipeline

Case Study

Petra Nova, Texas USA

Background

Located in Texas, USA, the Petra Nova plant is the world's largest carbon capture facility with a storage capacity of 5,200 short tons/day of CO_2. It is a joint venture between NRG Energy (NRG) and JX Nippon Oil Exploration (EOR) Limited (JX) and was designed to be a technology demonstration to identify any issues that would occur when scaling up the carbon capture process and integrating the technology. Any problems were well documented and can now be used as lessons learned for future projects.

The facility was able to capture 92% of the CO_2 released from coal-burning during its three-year demonstration period that began in December 2016.

Lessons learned for the supply chain

NRG's Ragen identified three relevant opportunities to drive down costs:

Streamlining procurement, reducing structural steel used, and other "learning-by-doing" generated by Petra Nova

- Gain a better understanding of where manufacturers are pushing their equipment envelope (size, performance, temperatures, pressures, environment, materials, etc.) and either select a more proven vendor (if one exists), or drill into the vendor's plan to address, and/or contract for more robust performance guarantees or warranties.
- Overseas fabrication may be a good alternative. Major vessels such as the regenerator, reclaimer, reboilers, and final discharge cooler were fabricated by two South Korean suppliers. Concerns over overseas suppliers of equipment and timely execution of orders did not manifest into critical path schedule impacts. The contractor managed its suppliers exceptionally well and when issues came up, they were addressed and resolved promptly.

Standardisation of design and pre-fabrication of modular components which can then be more rapidly and easily assembled on-site.

- Potential opportunities to reduce maintenance costs may have been missed by not standardising certain equipment to reduce the need for excess spare parts (e.g., pumps parts, cooling water heat exchanger plate packs).

Improvements in the efficiency and performance of the amine solutions used will reduce the amount of energy needed to run the CO_2 capture process

- Mitsubishi has stated that the construction costs of their Advanced KM-CDR process can be reduced by 30% because of trailing it at Petro Nova and have since developed an improved solvent.

Case Study

Northern Lights, Norway

Background

Shell, Total, and Equinor have teamed up on the Northern Lights project (launched in March 2021) to demonstrate how to capture, transport, and store CO_2 in the North Sea. CO_2 will be captured, transported via pipeline, and then injected into a saline aquifer 2,600 m under the seabed.

As part of the first phase of operations, Northern Lights is building two dedicated CO_2 carriers, each with a cargo size of 7,500 m3 and a length of 130 m. These will take captured and liquefied CO_2 from several onshore emitters and transport it to an onshore storage site before it is piped 100 km offshore to the storage complex Aurora.

Lessons Learned

Reservoir pressure was found to be a factor in deciding storage location.

It was found that a lower reservoir pressure meant the CO_2 was less compressed leading to an equivalent mass of CO_2 requiring a greater storage volume than it would at higher reservoir pressure. This must be considered when selecting a suitable storage facility

Overcame legal barriers

Previously, Article 6 of the London Protocol prohibited CO_2 from being transported across international borders to offshore storage. This posed a significant legal barrier to CCS. To proceed with the Northern Lights project, Norway and the Netherlands successfully argued for the provisional application of an amendment to the Article, allowing countries to export and receive CO_2 for offshore geological storage.

Capable existing supply chain

Although there are few comparable CCS chains worldwide, experienced, and competent contractors and suppliers can be mobilised and the technical know-how is readily available.

High cost

The net cost for capture, transport, and storage is high; for 800,000 mt, the cost is around krone 1,280 (£108.20)/mt, which will drop as the transport and storage facilities are used more.

Timelines

The time needed to perform detailed engineering and construct transport and storage facilities based on ships and a greenfield CO_2 receiving terminal is about three years.

Appendix F:
The NSTD — supply chain Transformation

- The Deal will help develop expertise to underpin growth in the domestic energy sector and subsequently in export growth markets, creating a globally competitive energy supply chain of international repute.
- The supply chain commitment focuses on supporting the transformation of the oil and gas supply chain to service low-carbon energy sectors at home and abroad. The sector has built a significant supply chain across the UK to support UKCS operations with aggregate revenue of £26.5bn in 2018.
- The UK's energy supply chain should be competitively positioned to seize such opportunities presented by offshore electrification, CCUS, and hydrogen both in the domestic market and internationally. As production from the UKCS declines, demand for the conventional services it provides will also fall, threatening the high-value jobs the industry creates. The sector will set its voluntary target of 50% UK content, including capital investment, over the lifecycle of all low-carbon projects, and offshore decommissioning, as well as 30% for locally sourced technology. This will be underpinned by the appointment of a supply chain champion for the sector. The government will invest £6.3mn in the Global Underwater Hub, and a further £2mn to develop the Deal, helping to support the sector to play a leading role in meeting the UK's Net Zero ambitions.

Supply decarbonisation

- The commitment focuses on actions the government and industry can take to reduce emissions from the UKCS oil and gas production, for example, electrification of offshore production installations and adherence to new standards on flaring and venting.

Carbon capture, use & storage

- The commitment aims to unlock investment of £2-3bn in CCUS transport & storage infrastructure from the sector, to underpin widespread capture rollout.

Hydrogen

- The hydrogen commitment focuses on creating an economic environment in which low carbon hydrogen production can flourish, which will help unlock billions of pounds of investment from the sector.

People & skills

- The Deal's 'People & skills' commitment contains actions that will both facilitate the reskilling of existing parts of the oil and gas workforce and ensure that everyone employed in the sector – whatever their background – can fulfil their potential.

There are sector and government commitments that make up the supply chain Transformation Commitments. The sector commitments include:

- Developing a UK low carbon supply chain of international repute
- Anchoring UK content in the supply chain
- Developing industrial-scale capability in the UK for the low carbon industry
- Promoting the energy supply chain's net zero capability and services to the world
- Attracting further inward investment for net zero
- Incubating new technology development
- Developing the Global Underwater Hub
- Championing the government's Prompt Payment Code

The government commitments include:

- Developing a UK low carbon supply chain of international repute
- Anchoring the UK local content in the net-zero supply chain delivering first-mover technology advantage
- Developing industrial-scale capability in the UK for the low carbon industry
- Promoting and exporting the supply chain's net-zero services to the world
- Developing policy to attract further inward investment for net-zero
- Simplifying funding access for new technology development
- Supporting development of the Global Underwater Hub

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