CCSA

Supply Chain Excellence for CCUS

July 2021

The CCSA

The Carbon Capture and Storage Association (CCSA) is the trade association promoting the commercial deployment of Carbon Capture, Utilisation and Storage (CCUS), an essential solution to help tackle climate change.

We work with members, governments and other organisations to ensure CCUS is developed and deployed at the pace and scale necessary to meet Net Zero goals and deliver sustainable growth across regions and nations.

CCSA members are drawn from a wide range of sectors developing CCUS, hydrogen and greenhouse gas removals – as well as the associated supply chain and service sector.

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Executive Summary

The CCSA estimates that expenditure on Net Zero CCUS (including hydrogen and greenhouse gas removals) projects could reach c.£41bn by 2035. Investment and ongoing expenditure of this size will deliver a huge boost to the economies of the industrial clusters on which most of these projects will be built.

This report demonstrates that not only will CCUS be vital for achieving the UK's Net Zero goal, but also the significant role CCUS will play in boosting the UK's prosperity and delivering the government's levelling-up agenda by supporting jobs and growth in the UK's industrial heartlands. We set out recommendations to maximise this impact by developing supply chain strategies to deliver long-term benefit to the UK and its domestic projects, and to ramp up the export opportunities created though international deployment of CCUS.

A successful Net Zero rollout will involve intensive project work all the way through to 2050 – a long-term prospect for industry. Current onshore major energy projects in the UK are themselves targeting a 50–60% UK content and offshore projects in the North Sea are targeting a 30% UK technology spend. If these levels of UK content persist, half of the estimated project expenditure could be spent outside the UK. A focused and effective approach to supporting UK supply chains could displace imports and capture a larger portion of the growth opportunity, providing domestic jobs and business, as well as securing export opportunities for the UK as other countries seek to develop CCUS.

Onshore

Around 85% of total expenditure on the deployment of CCUS and hydrogen is expected to be onshore in power generation, industrial capture, and hydrogen production plants. With its strong Engineering, Procurement and Construction (EPC) sector, and a need to construct plant on-site, the position of the UK engineering contracting industry looks assured. Studies and engineering design and cost exercises make up about 10% of the entire onshore spend, and engineering contracting another 13%. However, from a project execution perspective, the engineering construction industry will need to replace or re-train an ageing and non-diverse workforce by attracting tens of thousands of new and reskilled people into extensive training programs.

Offshore

At about £5bn, expenditure on offshore CO_2 transportation and storage projects to 2035 is much smaller than onshore expenditure. Nonetheless, offshore CCUS spend is a material piece of the current offshore expenditure and well within the recent capabilities of the existing supply chain. The supply chain in the offshore sector is coached towards excellence by the Oil and Gas Authority (OGA), and the new North Sea Transition Deal will support 40,000 direct and indirect jobs in decarbonisation projects. The sector contains UK-based companies which produce and export goods along with high-tech services based on cutting edge innovation.

Innovation – New Technologies

Although early major projects are expected to be conservative in their choice of technology, there are new technologies and techniques in development that offer compelling economic benefits. Some of these technologies change the nature of the supply chain required. Successful technologies which shift the emphasis from fabrication to manufacturing may suit the UK, which has a competitive manufacturing environment. The most compelling point for a country, contractor or vendor to capture supply chain value from a new technology is at its first commercial demonstration. Having successful new technologies demonstrated in the UK would undoubtedly boost the supply chain's export potential.

Skills – Training Diversity and Levelling-up

The lifetime cashflow of operating assets across the CCUS value chain is of the same order as the capital expense of construction. The ongoing operation of these facilities creates long-term jobs in the communities (clusters) which host them, as well as a pool of highly skilled people permitting further growth and a supporting service sector. In contrast to the construction sector, the expectation of some projects is that around 90% of the operational activity will be UK-based, and indeed much of that at local plants.

Infrastructure – Modularisation

Increasing competitiveness of UK companies is key to increasing UK content – particularly as no policy is expected which distorts competition or changes the UK's international position as an open country to do business in. One way of increasing this in terms of fabricating plant is to focus on techniques for modularising technologies and developing local facilities suitable for their manufacture. These modules incorporate a wide range of manufactured items and require several skillsets, providing economic and employment benefits for the UK with opportunity for long, integrated UK supply chains and the potential for export.

Supply Chain Management

The strength of the UK EPC sector and its export potential is an excellent platform for other UK supply chains to grow from. However, industry moving the dial further in favour of higher UK content, in line with Subsidy Control Bill as considered in Section 6, will need a re-energisation of competitive fabrication facilities and a responsive manufacturing sector for both onshore and offshore projects such as vessel, structure and module fabrication. Use of UK base materials such as plastics, composites and steel would by itself cause an appreciable increase in the value of UK content. Service sector industries can be expected to grow or reactivate domestically, partly through the presence of international and UK companies, but also because the UK is a successful innovator in the offshore sector.

More mature industries such as nuclear, oil and gas and steel have all used initiatives to improve their supply chains. A comprehensive supply chain strategy for CCUS, that focuses on identifying the early opportunities that have high potential to deliver long-term benefit to the UK is required if the UK is to make the most of the rapid increase in growth expected from a standing start.

Recommendations

This report sets out **five key recommendations** to take forward the development of supportive supply chain strategies:

1. **Clusters to work with industry and mobilise a cross-industry team to build on this report and develop supportive supply chain strategies for the CCUS industry.** Building on current analysis, undertake a comprehensive assessment of industry's current and latent capacity, technical excellence and cost effectiveness to provide a successful supply chain to CCUS clusters.

2. **Work with industry on the development of strategies for the following opportunities:**
   - Industry to review and identify which technologies/equipment would benefit from modularisation and standardisation and assess the potential for UK supply chains to competitively make fully modularised plants.
   - Project owners to promote policies and commercial constructs that can maximise the opportunities for UK companies as well as support them to export project expertise in CCUS technology.
   - Foster a UK-based supply chain, from novel low-carbon hydrogen production technology to compressors, meters and burners.
   - Industry to engage the UK base materials sector (e.g. steel, plastics, composites and hosing) to produce the products required by CCUS.
   - Government to identify opportunities to engage in the development of novel pre- and post-combustion capture, as well as BECCS and DACCS technologies which must be built to prevalence for the UK to meet its Net Zero target.

3. **Clusters to inform and prepare UK supply chains on the equipment and services that will be required by the emerging CCUS sector to avoid future bottlenecks and provide visibility for the near-future opportunities.** Working closely with cluster activities, produce a map showing the pipeline of projects across all clusters and advise and prepare the regional and national supply chain, including shipping, for future specific requirements.

4. **Industry to develop strategies that focus on creating skilled, long-term jobs, a diverse workforce and levelling-up the regions.** Identify long-term, skilled operating jobs and invest in appropriate skills and training to meet projected demand and provide high-quality jobs.

5. **Government to ensure effective delivery and coordination of UK supply chain activities.** There are a wide range of cluster, trade and industry groups carrying out work in this area and to be successful and ensure delivery of commitments set out in bids, the work must be strategic and closely coordinated.

1. Introduction

1.1 Background to the Project

Carbon Capture, Utilisation and Storage (CCUS) is expected to deliver a substantial portion of the UK's emission reduction targets. Government's ambition for 10Mt per year of CO_2 storage by 2030, of which 3Mt should come from industrial sources has been set out in the government's 10 Point Plan[1] and *Industrial Decarbonisation Strategy*. Ambition has been supported by substantial funding for industrial clusters to enable them to develop their long-term decarbonisation plans, and progress detailed technical studies on their anchor projects. Much of this expenditure involves CCUS.

Studies using energy system modelling of the UK[2,3,4] seek sequestration of around 100Mt per annum of CO_2 by 2050, compared with total UK emissions of c.450Mt per annum CO_2 in 2019. Around £200bn (see figure 4) of CCUS and related hydrogen project work and operational effort over asset lifetimes is required for the UK to meet its Net Zero target. Successful execution of these projects, many of which will be interdependent in clusters, is paramount.

For the UK supply chain to fully exploit this opportunity and maximise social and economic benefits to the UK population, it will need to offer timely delivery of high-quality, cost-effective products and services at high volume. There may be benefits to those supply chains which in themselves are low carbon when compared to alternatives.

The CCUS Council issued Terms of Reference in November 2020 for the Carbon Capture and Storage Association (CCSA) to embark on a collaborative program which aims at developing excellence across the UK supply chain. A four-phase program called Supply Chain Excellence for CCUS is envisaged stretching through 2021 and culminating in the embedding of long-term strategies between companies, in agreement with government. This report is the findings of Phase 2 – Opportunity identification. In addition to seeking opportunities for economic gain, the work will highlight the benefits such growth could bring both in terms of tackling diversity and the levelling-up of wealth and regions.

Phase 1
Project formation

Phase 2
Opportunity identification

Phase 3
Development of supply chain strategies

Phase 4
Embedding and sustaining the supply chain process

Figure 1: Supply Chain Excellence – CCUS Plan

1.2 Overall Project Plan

Phase 1 - Project Formation finalised the terms of reference and established governance, a core team and consultative and advisory groups, facilitated through the CCSA. Many organisations were contacted, including those with broader remits, not necessarily focused on CCUS, such as trade bodies and training companies.

A core group of seven expert organisations shaped the study and participated in study themes to provide valuable content for this report. A larger, broader group of over 30 individuals from relevant industries and organisations provided breadth and shared knowledge in larger plenary meetings in Phase 2. Both of these groups and additional external contributors provided further help in a series of one-to-one meetings. See Figure 2 below and Appendix 3 for further detail:

Phase 2 - Opportunity Identification, the main subject of this report, was a 3-month program aimed at identifying opportunities to improve the UK supply chain. Estimates of the size of the equipment types, engineering services etc required during the roll-out of key technologies were to be made and set against existing capabilities. Through interviews with group members and a review of publications, an overview of the potential opportunities and skill sets would be made.

Phase 3 - Development of Supply Chain Strategies will develop supportive supply chain strategies, building on Phase 2 and the publication of this report. A common purpose will be to ensure that in each relevant area identified there will be sufficient capacity, combined with technical excellence and cost effectiveness to succeed. In addition, the strategies will aim at significantly increasing skilled jobs and manufacturing competitiveness regionally and nationally.

Contracting strategies will be carefully designed to maximise economic growth and employment to the UK, whilst also benefiting contract owners and contractors. Such contracting strategies could include defining work packages that best reflect industrial sector structures; fostering learning by doing through phasing and consistency of design; and enabling a focus on best available technologies. All this must, of course, comply with the letter and spirit of competition law.

Phase 4 - Embedding and Sustaining the Supply Chain Process is a long-term activity designed to ensure that supply chain optimisation is well established among all stakeholders. A focused effort will continue to identify opportunities and maximise value. Securing the benefits of diversity and inclusion will be a key aim.

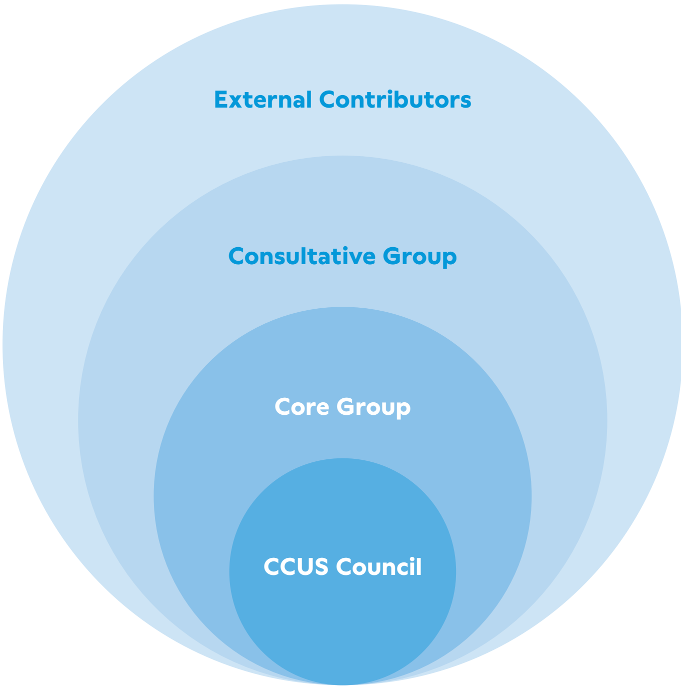


Figure 2: Organisation of the CCUS Groups

2. Phase 2 – Opportunity Identification

Following wide invitation, a kick-off meeting for committed organisations was held on 23 February 2021. It became very clear that a lot of the CCUS activities will stem from low-carbon hydrogen production, so in order to manage this overlap, the CCSA has engaged the Government's Hydrogen Advisory Council's Sector Development Working Group.

The three key work streams in Opportunity Identification are:

i) Estimation of the size of the CCUS supply chain needed for Net Zero (funding, people, skills) using literature, model outputs and questionnaires.

ii) Exploring themes to broaden understanding of industry through interviews.

- New Technology/technology dominance - can technological excellence build strong supply chains for domestic and export markets?
- Modularisation - can modularisation of technology favour UK supply chains?
- Legal issues and Supply Chain Management - identify the pressure points in moving towards more positive procurement positions for UK suppliers

iii) Estimate of UK resource requirement for UK Net Zero from databases and questionnaires.

2.1 Estimation of the size of the CCUS supply chain required for Net Zero

2.1.1 Methodology

Estimates of technology deployment in the CCUS/hydrogen arena, both in terms of capacity and timing, were based largely on the Sixth Carbon Budget from the Committee for Climate Change's Balanced Pathway CB06, and the Energy System Catapult's Net Zero Publications.[5,6]

Using standard sizes of plant, the number of units of each type required could be estimated, and capital and fixed operating costs rebuilt from published estimates, or estimates provided by the project's consultative group. These estimates contained breakdowns of design, equipment, contracting, labour costs which provided a measure of spend and resource requirements.

It should be noted that the outputs of this approach are open to challenge, as the models do not have perfect vision of future technology development. The methodologies used for onshore and offshore differ, and these, and the levels of deployment used in the estimates are outlined in Appendix 1 and Appendix 2.

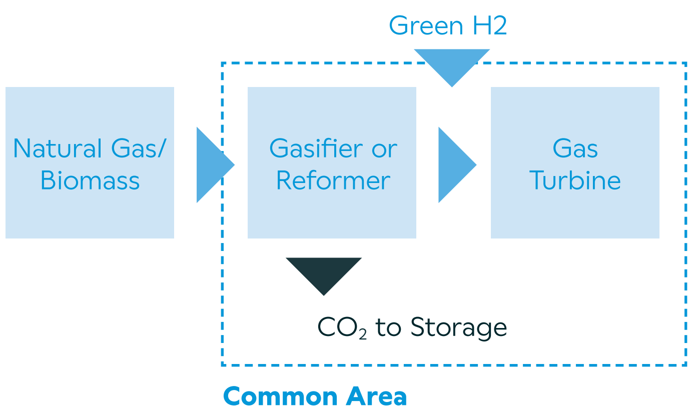


Figure 3: Additional hydrogen units in CCUS/hydrogen work

2.1.2 Overview of Spend

Capital and fixed operating expenditure are shown in Figure 4.

Capex and Opex of Technologies in CCUS/H2. Guidance from Net Zero Studies (CCC and ESC)	Total Installed by 2035	Total Installed by 2050	Total Capex Spent by 2035	Total Capex Spent by 2050	Fixed Opex 2035	Fixed Opex 2050	Basis for Opex
	£Bn Undiscounted						
ONSHORE							
CCGT/Capture	7.5GW	15 GW	17	28	19	33	25 years
H2 Turbines	3GWe	13.5 Gwe	2.5	15	3	16	25 Years
Misc Capture – inc Industry	5Mt/a	8Mt/a	2	3.5	2.5	4	25 years
H2 SMR from gas with Capture	60TWh	85TWh	6	8	7.5	10	25 years
EfW with CCS	<1MT/a	7.5Mt/a	<1	2.5	1	4	25 Years
BECCS Power	14MT/a	19 Mt/a	2	3	4	5.5	25 years (retrofit)
All Biofuels	2.5Mt/a	8.3Mt/a	3	11	2	6	25 Years
H2 Biomass Gasfn with Capture	5TWh	22TWh	1.5	5	1	4	
DACCS	<1MT/a	5	<1	3	0	3	
Onshore trunklines, compression	250kms	500kms	1	2	0.5	1	
OFFSHORE ***							
Offshore CO_2 Pipeline	800kms	1500kms	1.3	2.5	0.6	1.1	Store Life
Platforms	10 (plus subsea)	18 (plus subsea)	1.4	2.2	3.1	5.3	Store Life
Wells	62	101	1.9	3.1	1.8	3.1	Store Life
Other			0.2	0.4	1.7	2.5	Store Life
Abex					0.3	0.6	Closure
Shipping – CO_2 (not in model)*	9*1Mt/a	9*1Mt/a	<1	1	1.5	1.5	9*1Mt/a, 20y
TOTAL £bn			**41**	**90**	**50**	**101**	
National H2 Transmission (Not in model)**			Lifetime £30bn if fully deployed				

** Figures from BEIS "Shipping CO_2 - UK Cost Estimation Study, EE, Nov 2018"*
*** Figures from H2 Supply Chain Evidence Base , EE Nov 2018. Costs of repurposed Distribution are similar*
**** Figures based on PBD "UK Storage Appraisal Project". Ref 11.*

Figure 4: Estimated overall spend to 2035 and 2050, £bn, undiscounted

In general, the technologies presented in Figure 4 are representative of the current suite of CCUS cluster projects in the UK. For example, CCGT/CCUS is in the Teesside and Humber projects, and US projects under construction.

The TUC has estimated that 20GW of CCGT/CCUS, as represented in Figure 4, can create annual employment for 30,000 people.[7] Even if only half this is installed, 280,000 person-years will be required to execute the projects, of which 72% will be in mechanical and chemical engineering and construction crafts.[8]

Energy-from-Waste (EfW) with CCUS plants are being built in the Netherlands and potentially Norway, and there are two pre-Final Investment Decision (FID) biofuels projects in the UK, demonstrated abroad. Similarly, hydrogen reformer with CCUS and BECCS power are advanced projects. A considerable amount of biomass is needed to feed this portfolio, which is a supply chain exercise in its own right, and at this stage in development, it is difficult to pitch the relative costs of DACCS and some of the biomass portfolio. The costs for BECCS in Figure 4 are largely for retrofits to existing biomass power stations with established supply chains for biomass.

There is more uncertainty over the timing and importance of hydrogen turbines where co-firing mixtures of natural gas and hydrogen units looks technically assured. However, large frame flexible 100% hydrogen units are not yet available, although there is an industrial hydrogen gas turbine proposed in the North-West cluster project.

Many of the abatement technologies are composed of established technologies but are integrated in ways which have not been fully commercialised. Those which will be successfully demonstrated in full chain in the UK will attract significant attention from overseas companies looking for experience in how to de-risk their own projects, and therefore present an opportunity to monetise experience.

The model outputs lay down new plants at a reasonably linear rate to 2050. This long pipeline of design and construction work would offer a secure stream of work for the engineering and construction sector including EPC companies, particularly if they expand their existing strengths into BECCS and DACCS technologies in the future.

Offshore expenditure of the level shown in Figure 4 is material to the future of the sector, but below that of recent years in the North Sea,[9, 10] so it is reasonable to expect the existing supply chain to be able to meet UK needs.

To date, the UK content in the construction of UK projects of this size is surprisingly small. Vivid Economics[11,12] estimates that although UK content for services like project development, EPC, installation and operations exceed 90%, the value of UK goods bought for the projects is considerably lower; 19.9% for new build power, 56.4% for industry and power retrofits, 24% for CO_2 transport and storage and 41.2% for hydrogen. Based on this estimate, which is broadly in line with our other findings, about 60% of the £41bn would be paid to overseas companies.

Operational costs are similar to the capital spend, and offer high quality, long-term jobs in engineering and insurances, largely based in the industrial area itself. This develops communities open to the benefits of these technologies, creating pools of skilled people and experience that allow growth, and builds efficient stockist, maintenance and repair companies. In stark contrast to the capital projects, almost all studies expect the UK content of operations to be high – around 90%. With a successful track record and high standards and procedures, operational expertise and experience with licensed technologies is exportable, this includes, specialist services for offshore work or storage site development and analysis.

2.1.3 Analysis of Onshore Projects

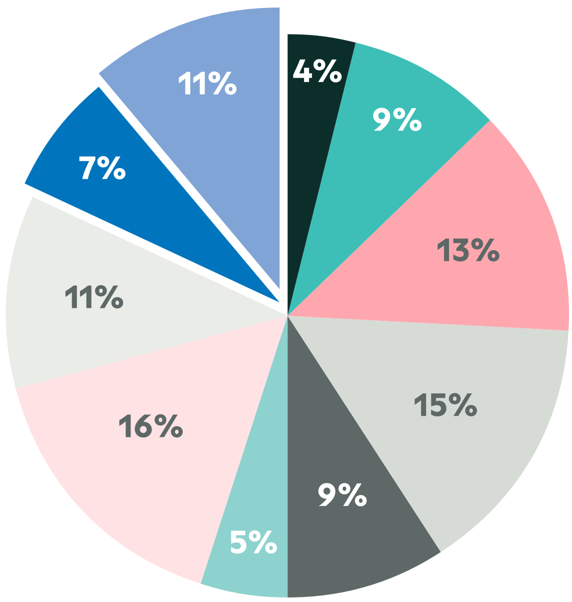
A breakdown of the total spend until 2035 for the project list in Figure 4 is shown overleaf in Figure 5 and consolidated into a chart. This is comprised of both people costs and hardware.

Design (9%) and EPC related costs (13%), along with costs of trades at site (15%), commissioning and owners costs (9%) all represent people costs related to the projects. There should be a high degree of confidence that the UK economy will benefit from a significant proportion of this. The total project engineering construction staffing totals about £15bn which is consistent with ECITB estimates.[14]

The bulk of the spend is in manufactured (11%) and fabricated parts (16%), and the current expectation is that overseas companies will supply much of what is needed based on their offering. Nevertheless, there is an opportunity for UK companies to increase their participation, given experience and capability in key areas. It is important to learn lessons from offshore wind and ensure that high-value and intellectual property related work is carried out in the UK, as well as the maintenance.

Finally, where the likelihood of retrofitting Combined Cycle Gas Turbine (CCGTs) with carbon capture units was lower than building a completely new plant, the costs of the whole build are included, including the cost of gas turbines. There are currently no UK gas turbine suppliers in a market that is difficult to enter and consequently packages of the gas turbine, Heat Recovery Steam Generator (HRSG) (11%), transformers and many other associated products (7%) are imported.

In terms of current UK projects, Keadby 2 is a CCGT construction project by SSE. They have chosen Siemens as their EPC contractor. The project targets a UK spend of 50% to build the plant, and a lifetime UK spend of 77%.[15] A CCGT and HRSG represent approximately 20% of the costs of CCGTs, therefore making significant increases in UK content would require the introduction of new highly specialised manufacturing capability in the UK from a low baseline. There may be other, more fungible parts or assemblies of the gas turbine package that could be brought to the UK, with the co-operation of the gas turbine manufacturer, who would have to qualify for UK support companies and products. Keadby (0.8GW) offers around 2,900 person-year jobs in construction.[16]



£m Spend pre-2035	
30% project contingency	
Site costs	4.3%
Solvent	0.2%
Feed	5.4%
Det. Des	3.6%
Vessels	1.6%
Col/react	0.7.1%
Exchanger	1.6%
Tanks	0.4%
Duct	0.5%
Cooling towers	4.8%
Eng services	12.6%
Commission	2.5%
Owner cost	6.0%
Pumps	1.6%
Filters	0.4%
Fans	0.7%
CO_2 comp	3.3%
Elec - Heavy (power)	7.1%
Control & insts	2.9%
Elec Bulks	1.8%
HRSG	3.6%
GT	7.3%
Pipe	5.3%
Labour - mech	10.0%
Labour E&I	0.2.8%
Labour – Civil	2.6%
	100%

Figure 5: Breakdown of onshore capital to 2035 [13]

Pre-combustion routes to lower emissions could offer a more promising outlook from a UK content perspective. The UK has opportunities to be strong in hydrogen production technology, as it has all the required R&D fundamentals coupled with compelling new technology options for low-carbon hydrogen with carbon capture and leading electrolysis technology for zero-carbon hydrogen. In addition, by developing existing strengths in hydrogen (and CO_2) compression and other associated manufactured items the UK could leverage expertise and increase the UK package. It will be important to take into account the total carbon intensity of products, as manufacturing in a regulated economy with a carbon price will result in comparatively higher costs. However, locally manufactured goods will have a lower carbon intensity.

The nuclear industry supply chain, which could also support CCUS projects, has been active over many years preparing for major projects. Hinkley Point C targets a 60% UK spend, and is buying considerable quantities of non-UK equipment,[17] so the value of initiating a change which increases UK content for future projects could be very significant. In addition, the presence of a large indigenous company specialising in key technologies like Siemens or EDF, can leverage sales into other countries like the UK.

The EINA study on CCUS credits the EPC sector alone (including the offshore industry) with an exportable value of £2.1bn per annum by 2050,[18] which is about 5% of the predicted global market, and about 50% of the total exportable value of CCUS.

2.1.4 Analysis of Offshore Projects

As with onshore assets, the operating costs to the end of the store life exceeded the initial capital. However, the store management skills, techniques and new devices used in the deployment of the stores will add a lot of exportable value to UK companies.[19] Appendix 2 shows a high-level draft injection plan consistent with CB06 injection rates, costed at best to *Order of Magnitude* level.

The spread of costs across the traditional components of pipelines, facilities (including platforms) and wells is shown in Figure 6.

Figure 7, shows the cost breakdown of an example storage project consisting of a NUI (4-legged platform), five wells and 100km of offshore pipeline.

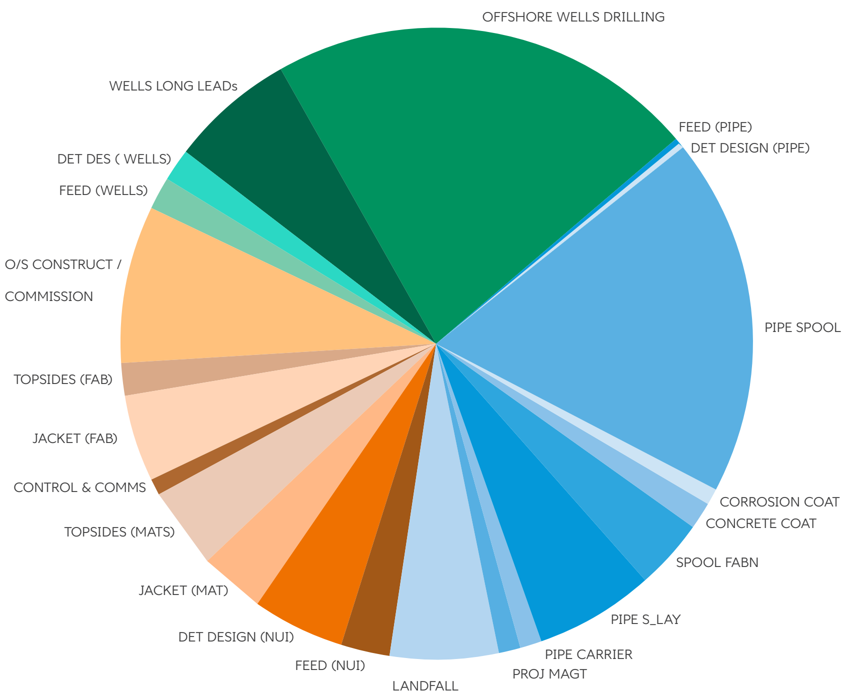
Capex to 2035, £m 2017	
Pipelines	1364
Wells	1916
Facilities	1408
Other	222

Figure 6: Capex breakdown to 2035, £5bn

Much of the spend for the offshore sector is concerned with heavy gauge metal in onshore pipe spool lines, jacket and topside fabrication yards, which until recently were commonly designed and built in the UK to service the UK oil and gas industry.

Clearly, the design, pipe spool and platform contracts are key targets for UK suppliers, along with offshore pipelaying and the drilling of wells. However, there is no equivalent to the large civil/construction/assembly contracts of onshore projects to guarantee a large UK market.

Currently, the offshore sector is working with government ondelivery of the North Sea Transition Deal which will support 40,000 direct and indirect jobs in decarbonisation. The sector is working with a voluntary target for its transition activities (including CCUS and hydrogen) of 30% UK content for technology and 50% for projects across their lifetime.[20] In terms of total spend however, this is numerically a smaller leakage than the onshore sector would be expected to incur. For some years the OGA has worked to improve the supply chain for offshore UK projects, and they are now assessing energy transition projects, through supply chain action plans and other processes. The UK oil and gas sector already exports services and specialist equipment to an international market. In terms of developing *Supply Chain Excellence*, the offshore sector is ahead of the onshore sector, so it may be more effective in Phase 3 to focus on stimulating onshore activity.



Cost £m 2017	
Feed (Pipe)	0.845
Det Design (Pipe)	1.56
Pipe Spool	65.6
Corrosion Coat	2.925
Concrete Coat	4.55
Spool Fabn	12.91875
Pipe S_Lay	21.9375
Pipe Carrier	3.9
Proj Magt	4
Landfall	20.3125
Feed (NUI)	8.45
Det Design (NUI)	16.9
Jacket (MAT)	11.57
Topsides (MATS)	14.95
Control & Comms	3.12
Jacket (Fab)	16.25
Topsides (Fab)	5.46
O/S Construct/ Commission	28.6
Feed (Wells)	6.283333333
Det Design (Wells)	6.283333333
Wells Long Leads	22.36
Offshore wells drilling	78

Figure 7: Example Cost breakdown for a single store
Pipe activity (blues), platform (oranges) and wells (greens)

3. Training, Diversity and Levelling-up

The Engineering Construction Industry Training Board (ECITB)[21,22] are developing strategies to ensure that the UK sustains a trained workforce which will enable it to meet the Net Zero target. Clearly the increase in workforce trained just to meet the demands of the CCUS and hydrogen activity is measured in the tens of thousands.

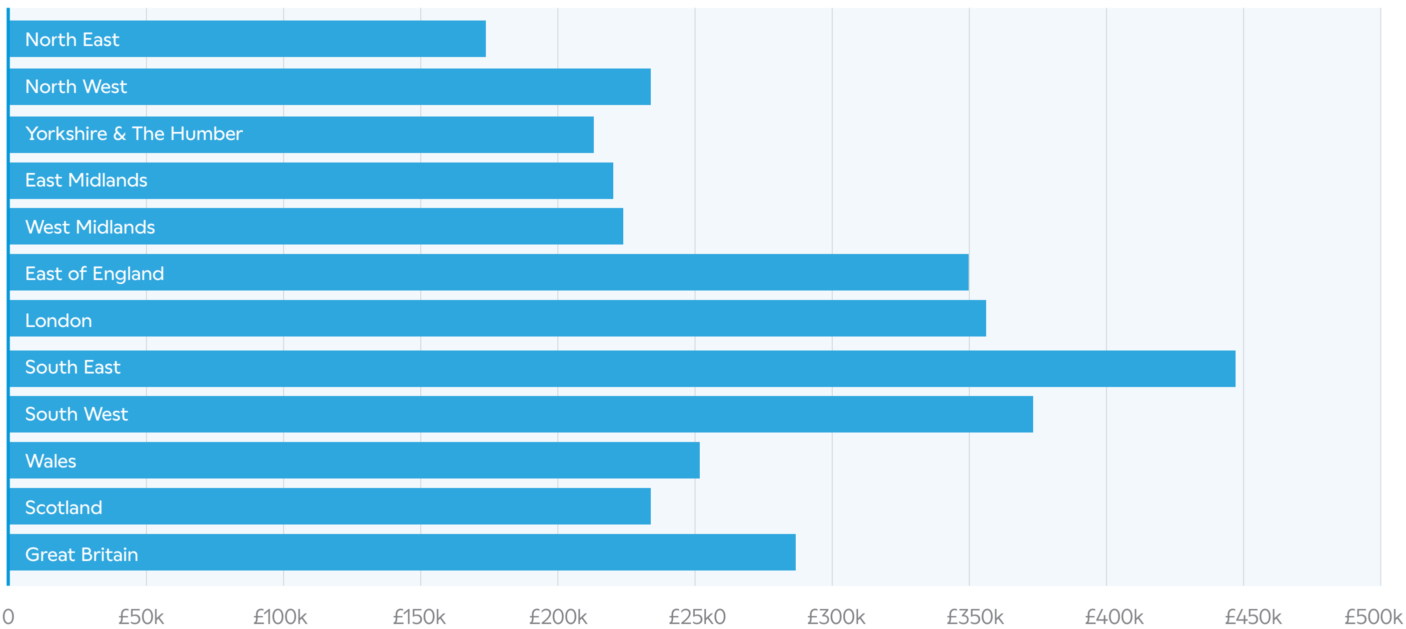
For example, the Net Zero Teesside project (a new build 2.1 GWe CCGT with carbon capture, two carbon capture retrofits and a hydrogen with carbon capture facility) will provide around 20,000 person-years of work during its development 2024-28,[23] which is still only a fraction of the total rollout in Figure 4. The current engineering construction workforce is ageing (one in seven workers will retire between 2020 and 2026) and is 88% male, with low BAME representation.[24] In addition, some industrial sectors like chemicals are already struggling to fill current positions. As such there is a great opportunity to refresh the labour force across these sectors.

The UK has seen workers leaving the declining oil and gas sector who could be redeployed into the CCUS offshore/hydrogen activity. There are currently 160,000 skilled people directly and indirectly employed in the offshore energy sector, including wind. This is expected to rise to 200,000 by 2030. The skill sets of offshore O&G work is easily transferred across the energy sector, especially to CCUS, easing the redeployment of offshore workers, whose numbers are likely to decline to 90,000 by 2030.[25,]

An ageing workforce and anticipated retirements will mean that substantial recruitment will still be needed for offshore energy projects, driven by offshore wind and the onshore sector overall will need to reposition the industry in the jobs market to make sure it is an attractive place to work.

Geographically, a growing CCUS sector can play a significant factor in levelling-up the economy in the UK with the provision of new permanent, skilled jobs. Key CCUS and hydrogen clusters in Humberside, the North-East, North-West, Scotland and Wales are all in areas requiring investment, and which have been falling behind economic growth rates in London and the South-East for many years.[26]

Median total household wealth by region, Great Britain, April 2016 to March 2018



Source: Office for National Statistics – Wealth and Assets Survey

Figure 8: Regional Variations in Personal Wealth – ONS[27]

4. New Technology

There are links between technology and the strength of supply chains, and participation in first commercial demonstrations can offer valuable opportunities for capturing supply chain value. In order to investigate further, a series of one-to-one interviews with technology owners was conducted to establish how the types and sizes of products and markets can impact the supply chain.

UK based technology licensors would normally sell technology from the UK and offer technical support services from the local office. In some cases, licensors will also supply materials (e.g adsorbent) from a trusted local supplier or retain a preferred local manufacturer of special equipment to maintain quality, reliability, safety and intellectual property protection, although in such cases an alternative supplier is developed for security of supply. In these scenarios, the UK would see leveraged export benefits from new technology development.

A different approach is taken for those selling into a more commoditised market, for example those selling modular plant in a competitive, busy market. Many of these technology providers are agnostic about the country of origin of their entire supply chain and will choose suppliers based on cost, quality and schedule, or to suit customer preferences. In these scenarios there is clearly less leverage from technology development.

Large operators are unlikely to risk unproven, new technology with such large, cross-chain investments. Post-combustion technologies have been demonstrated, or are being demonstrated abroad, and are therefore de-risked with cost reductions based on experience to be expected.

However, there are new offerings in development which offer substantial cost reductions and which if successful during the demonstration phases, will come to market, perhaps through smaller operators.

In order to capture maximum supply chain value from these new technologies, government should offer support and encouragement at the point of first commercial demonstration of a new technology, as this is the most compelling point for a country, contractor or vendor to capture supply chain value. Government should consider incentivising steel, cement, glass, petrochemical and other manufacturers to set up innovation spaces and provide a pathway, by which these could be accessed by technology developers.

Demonstartion plants attract interested companies, who may license the technology and often choose to use the same vendors for design and special equipment. In spite of some cost and schedule disadvantages, the UK holds several other advantages in this respect, but should manage regulatory issues in a way that does not discourage companies from deployment in the UK e.g. broad and commercially workable BAT regulation.

New technologies can change the shape of supply chains, by moving away from fabricated equipment to manufactured equipment, from steel towers to concrete (disruptive), common steels to exotic alloys. Although this study did not review the new technology landscape, there are some technologies which could reshape industry in the future. Some of these are set out in Figure 9 below.

Through various initiatives by government and the private sector, the UK supply chain has been put in position to supply specialist equipment to the top two technologies, for which the R&D work was carried out abroad.

Miscellaneous New Technologies **New Technologies can change the supply chain**		
CO_2 Power Cycle	Net Power	Novel GT, Combustor, exchangers, a materials challenge - small efficient plant)
CO_2 Capture on Adsorbents	Svante	Large rotating adsorber, new adsorbents - no solvents, offsite build of low structures
Centrifugal Adsorber & Stripper Columns	Baker Hughes 3C, Carbon Clean CycloneCC	Novel rotating columns – small transportable skids – low capex
Hydrogen Production	JM, Wood	High pressure CO_2 capture only – compelling cost reduction
Hydrogen Production	Coorstek	Protonic membrane – similar to battery cells HVM/robotic manufacture– very low energy penalty (currently low TRL)

Figure 9: Miscellaneous New Technologies and their potential effect on the Supply Chain

5. Modularisation

For many decades fabricated parts, assemblies and large modules for industrial plant have been produced in locations most favourable for their fabrication and assembly.

These fabrications are then shipped as large pre-assembled units or modules to a construction site for finishing and connections. Creating these units or modules includes the fabrication of plant pipework and vessels, subassemblies often containing machines (that are usually built elsewhere) and attaching control systems and auxiliary services, all within a large, moveable steel structure (Figure 10).

Figure 10: Compression Module leaving yard: Courtesy Wilton Group

Modular assembly is the most practical way of creating offshore plants, but it is also used extensively for onshore plants where access to the sea is available and local construction of the plant (stick-built) is sub-optimal due to reasons such as a shortage of skilled labour or adverse climatic conditions.

The UK has built many such large pre-assembled units in its fabrication yards in the past, largely but not exclusively for use in the Oil and Gas sector, as bespoke units. Many of these yards have now closed or diversified, but some UK fabrication businesses still exist and actually export. UK fabrication costs are generally higher than Southern Europe and Asia, even following adjustments for logistics costs and applicable import duties and tariffs. Meeting Net Zero will create a huge increase in demand for pre-assembled units and the UK would need to address a number of factors to compete for orders by developing a more viable and sustainable UK alternative:

- **Labour costs and productivity:** Base labour rates are high and other considerations widen the gap and increase labour costs. The UK also has relatively active industrial relations which can limit the productivity and flexibility of the labour pool in comparison to its international competitors.
- **Raw material costs:** International fabrication yards are able to utilise low-cost sourcing strategies to secure raw materials, components and equipment, at favourable rates when compared to the UK. These international yards are often geographically better positioned to take advantage of these markets leading to improved lead and delivery times, and lower logistics costs.
- **Fabrication yard efficiencies:** UK fabrication has developed over a number of years around certain historical markets which has impacted their geographical location, connection to key infrastructure links and the size and layout of their facilities.

  Conversely, many of the international yards have been developed with the sole purpose of fabricating and assembling modules in the most efficient manner possible, and benefit from significantly better layouts, scale and efficiencies than those in the UK.

One current initiative to improve the efficiency of manufacturing is the Made Smarter initiative which focuses on maximising use of digital technologies across all manufacturing activities.[28]

Some carbon capture technology suppliers are offering plants in fully Modularised form. This means they move away from bespoke one-off builds and produce plants in a limited number of sizes, which are all easily transported to site, for example; 0.04Mt per year CO_2 and 0.1Mt per year CO_2 capture 'units'. A small to medium sized modular approach works in the marketplace as much of the total emission is from medium sized and smaller sources, and many large emitting point sources such as refineries are actually a combination of several smaller emitting units.

In order to work economically, modular plants are produced by a closely integrated supply chain, including the designers, fabricators and their suppliers and delivering contractors. Costs are driven down by process intensification, repeat designs/orders and working in a suitable environment in terms of labour, access and working environment. The bigger the scope of the module, the more cost effective it is likely to be. A long pipeline of orders must be expected to make the upfront investment worthwhile for all.

A change in mindset is also needed from the operators, who would be buying a product rather than building a new plant on site to their in-house standards. Operators meet their growing demand by purchasing multiple units. Customers benefit from improved reliability due to a faster learning curve, shorter project schedules and access to common spares.

Modules can come in packages with the dressings required to complete the plant assembly (although they may not be transported fitted), so there is an opportunity not just to export fabrication, but much other manufactured equipment, and of course the labour content used in assembly.

The approach can be further improved by standardisation of components within the modules and elsewhere across the industry, which will significantly increase volumes of individual components and reduce the number of fabrication procedures. As a result, more of the plant could be made directly from manufacturing processes, including robotics, than by bespoke fabrication. The UK could potentially learn from our successful manufacturing industry in automobiles e.g. Honda and Nissan, in terms of management and leadership approaches.

The recent expansion in the Freeport areas may boost well positioned fabrication yards and will certainly help prospective project owners located inside them. Under developing proposals these would be able to import materials without customs and duties and construct new clean growth plant for local use or barge to the North Sea. Fully imported products from the Freeport areas may see reduced tariffs.

To compete in this type of market, the UK needs to:

- Identify the technologies most appropriate for modularisation/standardisation (robust and not necessarily UK inventions)
- Identify and test the UK market for willing collaboration teams
- Apply learnings from other UK successful industries e.g. Honda and Nissan
- Map out fabrication yards, scoring for suitability against world class facilities
- Set out a roadmap and achieve buy-in to ensure this can be delivered at speed
- Increase the focus and production processes on carbon intensity in supplier selection

6. Legal Considerations and Supply Chain Management

A combination of laws including Subsidy Control and Competition Law and government policies have ensured that the UK remains an open market for UK to do business with foreign countries and vice versa.

UK industry, and NE Scotland particularly, has thrived without hard local content requirements, creating thousands of local jobs and a globally recognised deep technical expertise base over the last five decades. Local content requirements are barred under WTO rules as well as the Trade and Cooperation Agreement with the EU. Post-Brexit, there are no signals that laws and policies will change this, in particular, any requirements or agreements creating an uncompetitive market distortion in favour of UK companies are not expected to emerge.

The World Bank[29] defines local content of a supply chain as the share of employment – or of sales to the sector – locally supplied at each stage of the chain. In terms of employment, local companies, foreign companies with local offices and staff, and even UK companies supplying services from abroad all contribute, to varying degrees a share of the employment projects offer. The same definition of local content can be applied for goods used in construction phase and even operational costs during the asset lifetime. Globally, expectations for local content in projects stem from a wide range of deals from clauses in commercial contracts to voluntary targets for government assurance. Project owners and contractors deal with these in several ways, and have different strategies depending on the obligation, the ability of the local country to supply and the presence or not of other international suppliers in the region.

Often the definition of local content is broadened to include local benefit and provision of community assets, technical training, research and development initiatives, as well as technology support centres. Objectively, there can be more potential benefit to society in investing in these types of local initiatives than adding risk to the project and supporting companies which may not survive and be able to compete in the long-term. For companies operating internationally, hard local content requirements risk pricing projects beyond a global investment threshold. When devising strategies to promote local content therefore, it is worthwhile considering what might be lost to the hosting country and project.

Outside the Asset Owner and EPC world, judging what is local content can be difficult in a sector where markets are international. UK registered companies can be sales offices for companies that do not produce anything in the UK. Many manufactured products use a suite of foreign components or sub-assemblies. Others have foreign parent companies but employ large numbers of UK staff to make some of their products and execute services, both for domestic and foreign projects, so again strategies must be clear about what benefits the UK overall.

Some invitations to bid for contracts outside the UK have criteria which examine the carbon emissions associated with product creation or project execution. The UK steel sector could benchmark well against key competitors in this respect, particularly if decarbonisation plans are fulfilled promptly. However, for a CCUS project such as CCGT with carbon capture, the emissions saved by procuring cleaner or green steel and concrete are small compared to the lifetime residual emissions of the plant. This therefore needs strategic consideration at cluster or industry level to make it work. If low carbon materials are not required in a bid, competing EPCs cannot be expected to add them in.

The UK government included economic benefits in its evaluation criteria for the cluster sequencing.[30] This incentivises projects to seek UK suppliers for their application process, however it is important that mechanisms are put in place to ensure successful clusters deliver on the commitments made in bids.

Currently project owners and EPCs have long-term, global supply contracts with preferred suppliers and qualified vendors that will not have strong UK representation in key areas of spend. Qualifying for bids, particularly in new fields can be very challenging, especially as reputation and previous experience is an important requirement. Documentary requirements will contain company, organisational and personnel qualification as normal, but will also contain requirements for equipment schedules and management systems for Quality, Health & Safety and Environmental Management, complete with policies, procedures and certificates.

The steel industry has a Charter which fosters use of UK material and helps companies in the supply chain to be selected.[31]

7. Strength of the UK Supply Chain

7.1 Onshore

As discussed throughout the report, the engineering design and contracting sectors are strong and have adapted to face the emerging CCUS markets at home and abroad. Smaller, less established technologies like biomass and waste plants are however, often led by foreign technology and contracting companies in the UK.

The strength of the UK supply chain for fabricated equipment and machinery for this industry was assessed qualitatively using a database of vendors and a questionnaire sent to a contributing EPC contractor. The questionnaire provided information on the strength of supply down to equipment item level. For post combustion CO_2 removal plant (fabricated vessels, exchangers etc) and machinery (pumps, compressors etc) much of the total required (about half by value) had a very weak UK supply chain – "less than 3" (feasibly zero) potential vendors were visible to the EPC, and the chain for those items was assessed as low on capacity, capability and experience. Where the chain was strong, it still had to compete with foreign companies. Similarly, UK vendors supporting the construction of hydrogen production plants were not strong either – if the UK's promising hydrogen production technologies are to be fully exploited, work needs to be done activating the supply chain.

Fabrication yards, which blossomed to support the oil and gas sector have been closing due to lack of work, with some exceptions diversifying into wind, defence and other sectors. This project only identified a handful of large, high quality fabrication shops for special "onshore" vessels.

However, if demand were to increase and the environment and conditions were appropriate, there is no reason why yards and shops could not return.

UK industrial manufacturing to support CCUS such as pumps, compressors etc looks weak and much of the supply chain (not just steel) is expecting to struggle with the Covid downturn for the next 18-24 months.

The UK steel sector faces an ongoing and challenging competitive environment.[33] From the perspective of a supply chain for CCUS, it obviously will need to competitively make the right steels in the right format for the particular structures and pipes common to this emerging market. For example, there are only two pipe-making companies left in the UK. The Industrial Decarbonisation Strategy gives visibility on how the sector can position itself to reach near-zero emissions by 2035, in line with the Climate Change Committee recommendations.

7.2 Offshore

The current supply chain is bigger than that needed for the mature UKCS and Net Zero. The UK demand for oil and gas is declining, and the North Sea Transition Deal will help secure a transfer of skills into CCUS. Nevertheless, the UK's geological R&D and contracting capabilities, its high-tech products and offshore operational expertise is strong and bodes well for the UK to be a leader in this field. The supply chain practices are stewarded by the OGA and its recommended processes.

8. Conclusions and Major Opportunities

Current onshore major energy projects in the UK are targeting a 50–60% UK content and offshore projects to be 30% UK content. Consideration of lifetime expenditure raise these figures to around 70% and 50% respectively. Expenditure on Net Zero CCUS build projects could reach c.£41bn by 2035, mostly onshore. Without intervention, about half of this money will be spent abroad.

More than half total expenditure is in the operational phase of the asset, rather than its construction. These offer well paid, long-term jobs in the communities in which the assets sit, which are generally in regions requiring employment support.

The EPC industries make up over a fifth of this spend, and the UK has an excellent opportunity to exploit this at home and abroad. Staying close to successful technology developers, both incumbent and future ones, tackling new opportunities including DACCS, biomass and waste projects and being involved in demonstrations will be important.

New process technology is an enabler for the UK's future, not so much in the short term, but in the longer term, as the landscape now has some more radical options to cut costs. There may be more "open space" in pre-combustion technologies than in the post-combustion ones which may dominate early projects.

It is not possible to move the dial significantly on the existing expectation of UK content without securing a good environment for fabrication. Building excellence in modularised construction is seen as a good way of securing market-share and exporting goods with a high UK man-hour content. Modularisation pulls in the whole supply chain, as it can encapsulate all types of equipment and trades. Demands for trade skills will be much sought after across the whole energy sector and needs to be refreshed to attract a diverse new workforce in the medium and long term.

Another fundamental piece of the supply chain as far as UK content is concerned is steel and pipe spool manufacture – across the chains potentially the largest single spend element – where our positioning looks to be weakening further at the wrong time.

The UK lacks production of gas turbines and other specialist rotating equipment, which is a multi-billion pound prospect in the UK alone. Starting production here, from a low technical baseline will be challenging and will have high entry costs. Selection of a sector of this market to strengthen, say high pressure hydrogen or CO_2 compression, may be more secure and sustainable.

Our expertise in high-tech devices and the services they support (e.g. subsea vehicles, PCB exchangers) are powerful at reducing costs and are great flagships to export services from the UK.

There is an international supply chain waiting to profit from the UKs decarbonisation programme. Seizing any of the above opportunities to secure and grow the UK content of our projects is an urgent activity, as the lead time to develop supply chains and their products will be several years long, and the ground-breaking projects are already being designed, and will begin soon.

APPENDIX 1: Methodology used to estimate Onshore Costs

Methodology: Resources needed for Net Zero 2035/2050

Onshore

- The deployment of the various technologies was estimated using data from the CCC's CB06 and the ESC's Net Zero publications. Where these conflicted a view was taken, shaped by the visibility of deployment in recent projects. The chosen deployment values for each of the technologies is shown in Figure 11 overleaf. A 2035 horizon was added to the 2050 one, as the deployment in that timeframe is seen with more certainty.
- Standard plant sizes were selected for each technology and the number of plants calculated. For newbuild plant with CCUS, the costs of the core technology were included (e.g. include the gas turbine in a CCGT with CCS), but where retrofit is more likely, the cost of the CCUS alone is tabulated. Large scale low-carbon hydrogen units and turbines were included.
- Using up to date cost estimates (ibid[34] Pale Blue Dot (2016), Progressing Development of the UK's Strategic Carbon Dioxide Storage & SNC-Lavalin (2017) Detailed Report: Plant Performance and Capital Cost Estimating Doc Number: 181869-0001-T-EM-REP-AAA-00-00004 Revision A07 and Wood (ETI-funded)) in the public domain, or provided by the group, the capital cost of the Net Zero deployment and its fixed opex costs were rebuilt. Costs are undiscounted/unadjusted in £ 2017. Published capex and opex estimates were used to break down the cost spend into different categories. Infrastructure costs (e.g shipping, major pipelines) were not extracted from models, but were estimated based on publications, including those published from previous CCUS competitions.[35]
- CO_2 shipping is not modelled in ESME – international ships fuel emissions are. Allowance was made for 9*1Mt/a systems, reflecting that Milford, Port Talbot, Southampton, Isle of Grain and several other locations may start this way. Costs were taken directly from Shipping CO_2 – *UK Cost Estimation Study Final report for Business, Energy & Industrial Strategy Department November 2018*, for example Figure 6.5.
- Key selected technologies include conventional steam methane reforming with carbon capture to produce low-carbon hydrogen, Class H gas turbines, post-combustion capture with advanced solvents for all post-combustion, hydrogen turbines (with associated infrastructure) from a published report by Atkins.[36]
- It was assumed that gas turbines were initially built as single turbine assets until 2035 when these could be doubled up. Similarly, hydrogen gas turbines are initially single devices or retrofits until 2035 when large hydrogen gas turbines become available and require infrastructure to allow them to be dispatchable.
- Where retrofits were built, it was assumed derating of energy production due to capture plant needs was tolerable, and no capex was spent to replace it. All biomass power was retrofits (notionally Drax and MGT). It was assumed that early in their life, units ran at high load and high availability.

Figure 11: Technologies deployed –size

Capex and Opex of Technologies in CCUS/H2. Guidance from Net Zero Studies (CCC and ESC)	Total Installed by 2035	Total Installed by 2050	Total Capex Spent by 2035	Total Capex Spent by 2050	Fixed Opex 2035	Fixed Opex 2050	Basis for Opex
	£Bn Undiscounted						
ONSHORE							
CCGT/Capture	7.5GW	15 GW	17	28	19	33	25 years
H2 Turbines	3GWe	13.5 Gwe	2.5	15	3	16	25 Years
Misc Capture - inc Industry	5Mt/a	8Mt/a	2	3.5	2.5	4	25 years
H2 SMR from gas with Capture	60TWh	85TWh	6	8	7.5	10	25 years
EfW with CCS	<1MT/a	7.5Mt/a	<1	2.5	1	4	25 Years
BECCS Power	14MT/a	19 Mt/a	2	3	4	5.5	25 years (retrofit)
All Biofuels	2.5Mt/a	8.3Mt/a	3	11	2	6	25 Years
H2 Biomass Gasfn with Capture	5TWh	22TWh	1.5	5	1	4	
DACCS	<1MT/a	5	<1	3	0	3	
Onshore trunklines, compression	250kms	500kms	1	2	0.5	1	
OFFSHORE ***							
Offshore CO_2 Pipeline	800kms	1500kms	1.3	2.5	0.6	1.1	Store Life
Platforms	10 (plus subseas)	18 (plus subseas)	1.4	2.2	3.1	5.3	Store Life
Wells	62	101	1.9	3.1	1.8	3.1	Store Life
Other			0.2	0.4	1.7	2.5	Store Life
Abex					0.3	0.6	Closure
Shipping – CO_2 (not in model)*	9*1Mt/a	9*1Mt/a	<1	1	1.5	1.5	9*1Mt/a, 20y
TOTAL £bn			**41**	**90**	**50**	**101**	
National H2 Transmission (Not in model)**			Lifetime £3bn if fully deployed				

** Figures from BEIS "Shipping CO_2 - UK Cost Estimation Study, EE, Nov 2018"*
*** Figures from H2 Supply Chain Evidence Base , EE Nov 2018. Costs of repurposed Distribution are similar*
**** Figures based on PBD "UK Storage Appraisal Project". Ref 11.*

APPENDIX 2: Methodology used to estimate Offshore Costs

Offshore

- The required injection rate for CO_2 was also taken from the CCC's CB06, balanced pathway scenario.[37]
- Building on previous work by Pale Blu Dot, an injection plan and sequence of stores was sketched out which matches the required injection rate, see Figure 12 below. Insufficient storage and injectivity to meet CB06 had been appraised and costed in the reference, so additional known stores which had been scoped out by the project were added to the plan and costed by analogy. Note this is purely for resource estimation, and results give an Order of Magnitude estimate.
- Using the data in the reference to provide a breakdown of expenditure in different categories, breakdown of costs for an exemplar store based on Bunter store BC36 was mapped in Figure 7.
- Opex quoted contains some energy use and other factors not related to the supply chain and could not be reduced to simple fixed costs, but gross electricity usage for the temporary heating of CO_2 prior to injection of highly depressurised stores was deducted where possible.
- Where re-purposing of pipelines were part of mature projects, it was assumed they were reused for the duration of the store.
- Costs were adjusted to £2017, but left undiscounted – no inflation, learning rates etc were applied.
- Each store has its own pipeline – no store benefits from new infrastructure laid down for other new stores.

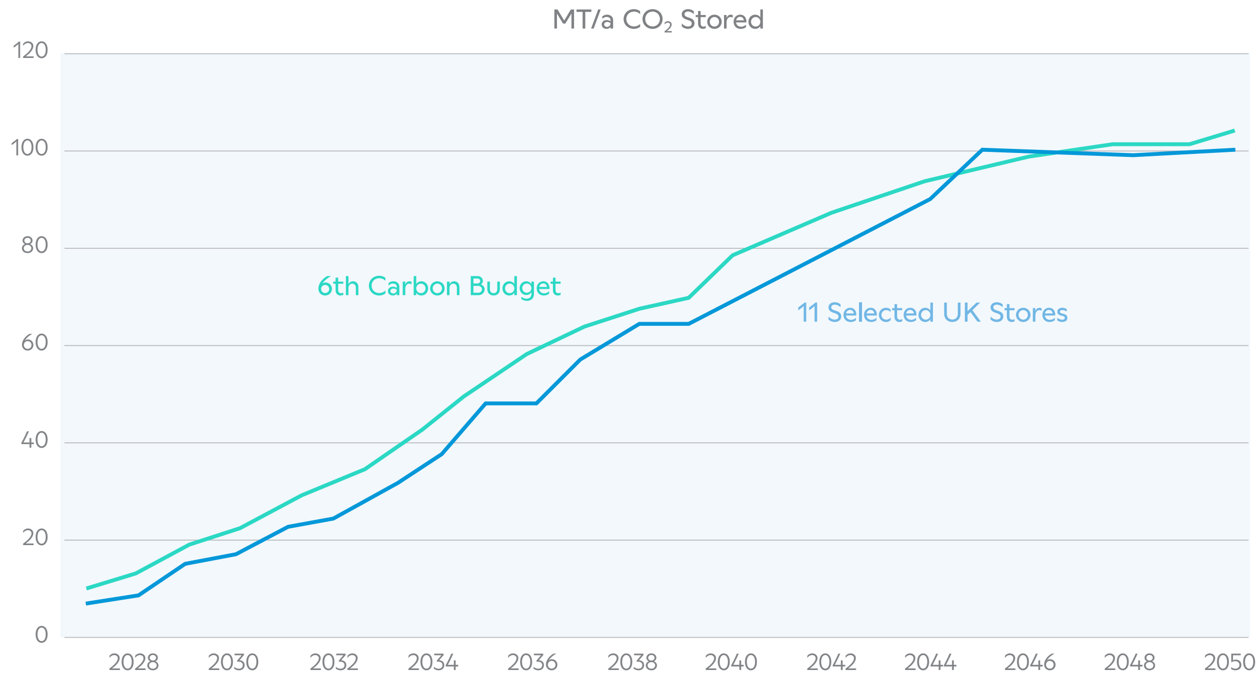


Figure 12: Matching store injection plan to emissions in CB06

Outline Roll -out costs - offshore NZ						PIPELINE					WELLS					FACILITIES					OTHER				INCLUDING			Pre/ Post 2035
REGION	STORE	PROJECT	TIMING DRIVER	RATE	YEARS	PIPELINE	CAPEX £2015M	OPEX	ABEX	Ref. PBD Report	WELLS	CAPEX	OPEX	ABEX	Ref. PBD Report	FACILITIES	FACILITIES COST	OPEX non heating	ABEX	Ref. PBD Report	CAPEX	OPEX	ABEX	TOTAL COST (REAL)	FEED	Other preFID	Detailed Engineering	
PETERHEAD	Captain	Acorn	"2 stores by mid 2020s", "10Mt/a CO_2 and 5GW H2 by 2030"	5	25	78km Atlantic + 8km new	22	50	23	25 & ref2	3+1	110	60	28	25 and ref 2	1 umbilical, 4 subsea	130	0	13	16 doubled	14	106	63	619	3.3	11.8	10	All Capex pre 2035
	Mey		CB06 Net Zero 2035	5	60	180km Miller + 27Kms	75	106	40		4	110	220	84	16 analogue	1 umbilical, 4 subsea	229	0	23	Ref2	18	106	48	1059	4	12	10	All Capex pre 2035
	Forties 5		CB06 Net Zero 2050	8	40	New -216kms *24"*+ 24km*12"	373	190	53	23	6+6	437	282	97	23	6 slot NUI, 4 slot subsea	123	360	54		91	609	293	2962	17	86	27	All capex post 2035
MERSEY	Hamilton	Hynet	"2 stores by mid 2020s", "10Mt/a CO_2 and 5GW H2 by 2030"	5	25	Hamilton	12	11	6	24	2+2	98	77	28	24	6 slot NUI	107	208	40	24	11	81	19	698	16	5.5	21	All capex pre2035
	S Morecambe		CB06 Net Zero 2035	15	60	New - 24" *83KM	161	97	23	24 and 6	5+5+5	336	693	84	27 analogue	6 slot NUI *3	309	1498	120	27	15	583	60	3978	16	12	25	c.30% capex pre2035
HUMBER	Endurance	Zero Carbon Humber	"2 stores by mid 2020s", "10Mt/a CO_2 and 5GW H2 by 2030"	13	40	New - 24"*90Km	177	67	25	analog	16	464	300	90	by anaogue	Costed as 2 *NUI, probably NUI plus subsea	135	297	100	by analogue	80	400	80	2216	17	12	27	All capex pre 2035
	BC36		CB06 Net Zero 2035	7	40	new - 20"* 160kms	230	120	33	22	4	294	112	57	22	12 slot NUI	102	320	58		42	199	40	1607	12	39	21	All capex 2035
	Viking	Humber Zero	CB06 Net Zero 2035	5	25	20"*185km	224	74	32	26 adj	2+1	83	52	24	26	4 slot NUI	140	412	38	26	10	103	14	1206	19	7	21	All capex pre 2035
	BC03		CB06 Net Zero 2050	12	20	New 20"* 238kms	340	65	49	9	12	252	280	63	9 analogue	3 *NUI	321	353	120	analogue	10	80	20	1952	16	12	27	All capex post 2035
THAMES	Hewetts		CB06 Net Zero 2035	10	20	new - 36"* 250km	360	68	51	13/ Kingsnorth KT, Ref1	4+8	276	330	69	Kingsnorth KT	12 slot NUI, plus subsea	150	360	47	guess	15	80	30	1837	10	12	27	All capex pre 2035
	BC09		CB06 Net Zero 2050	15	60	new 36"* 194kms	360	205	51	9	15	375	693	94	analogue	6 slot NUI *3	306	1440	120	analog	42	200	40	3926	24	39	27	All capex post 2035

Figure 13: Store Plan for Cost Estimation purposes

APPENDIX 3: Acknowledgements

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Liberty Steel
Linklaters
National Grid
NECCUS
NPL
OGUK
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TTE
TVCA
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Wood
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