

elementenergy



*Developing a CCS network
in the Tees Valley Region*

Final report

for

**One North East
And
NEPIC**

21/12/10

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Element Energy Ltd is a low carbon consultancy providing a full suite of services from strategic advice to engineering consultancy in the low carbon energy sector. Element Energy's strengths include techno-economic forecasting and delivering strategic advice to clients on all opportunities connected to the low carbon economy. Element Energy has experience in the design of strategies for the coordinated deployment of low carbon infrastructure

Carbon Counts

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Non-technical Summary

Tees Valley manufacturing industries are critical to the overall prosperity of the North East of England. The future commercial viability of several of these businesses is at risk because of increasing financial exposure to rising costs of compliance with regulations designed to restrict carbon dioxide (CO₂) emissions to atmosphere and attendant competitiveness effects this could drive in global markets. Limiting this exposure will be critical to avoid businesses relocating production to jurisdictions which do not face such threats.

The UK has adopted challenging targets to reduce emissions of greenhouse gases. The North East industrial and power sector emitters will need to play their part if these targets are to be met. Whilst some measures such as energy efficiency and fuel switching may offer incremental opportunities for CO₂ emission reductions, carbon dioxide capture, transport and storage (CCS) technologies offer the potential for step-change reductions in CO₂ emissions from large emitters. Within the UK, the Tees Valley is well placed to implement CCS as:

- Deploying CCS in the Tees Valley could provide ca. 8% of the UK's required CO₂ reduction by 2030.
- The Tees Valley has access to diverse storage options beneath the North Sea.
- CO₂ emitters are close to the North Sea coast and are densely clustered within a few kilometres of each other, making an onshore pipeline network low in cost and comparatively easy to deliver.
- The costs of implementing CCS in the Tees Valley are expected to be comparable to forecast CO₂ prices in the period 2020-2030.
- Businesses in the Tees Valley are familiar with CCS technologies and are used to handling complex infrastructure development projects.

This report examines a number of options for transporting CO₂ from a number of candidate sources in the Tees Valley to storage sites beneath the North Sea. An integrated CO₂ pipeline network of between 14-22 MtCO₂/year capacity – including a common hub and offshore pipeline – could offer a more cost-effective and convenient long-term option than one where each emitter builds their own dedicated pipelines in a piecemeal fashion. The likely net cost of service for CO₂ transport would generally be cheaper, although this view is sensitive to numerous assumptions, most notably the distance offshore, cost of financing and rate at which the pipeline achieves full utilisation.

The UK and European CCS demonstration programme provides an early window of opportunity to develop a CO₂ pipeline network in the period 2015 to 2020. However, additional funding would be needed to cover the incremental cost of the “future-proofed” integrated network. Public funding, policy and regulatory clarity, and equity investment from well capitalised businesses will likely be required to de-risk the project and unlock additional finance, particularly if private sources of project finance are sought.

Whilst a range of options exist for structuring an investment – including government and single-entity led developments – a Joint Venture special purpose vehicle established by regional operators appears to be the most viable near-term approach. Tees Valley businesses already have considerable experience of joint infrastructure development and management, and could therefore rapidly mobilise the necessary arrangements absent of a public regulator that could oversee the developments of a CO₂ transportation “market”.

This report makes 8 recommendations for local stakeholders to work together to facilitate the development of a CCS network in the Tees Valley. These are summarised below (and listed in full within the report).

1. Improve the organisation of stakeholders in a North East CCS network.
2. Use this organisation to remove barriers and assist the development of a North East CCS network.
3. Provide stakeholders with an independent assessment of CO₂ storage options for the North East.
4. Strengthen and support the business case for CCS anchor projects and a CCS network in the North East.
5. Include CCS within local planning policies.
6. Explore public/NGO support for CCS deployment in the North East.
7. Continue to support other options for CO₂ reduction (to reduce CCS costs).
8. Examine the impacts of pipeline entry specifications on the costs and feasibility of CO₂ capture and compression for North East emitters and potential storage operations.

Executive Summary

Tees Valley manufacturing industries are critical to the overall prosperity of the North East of England. Recent years have seen inward investment of more than £800m from international businesses and further investment worth £8 billion pounds is under consideration.

The future prosperity of the Tees Valley is threatened by rising CO₂ prices within the EU emissions trading scheme. Nearly forty wealth generating businesses in the Tees Valley emit more than 50,000 tCO₂/year and eight of these are forecast to emit on average more than 1 million tonnes (1 Mt) of CO₂ each year. If the impacts of future CO₂ prices and regulation are not addressed it is possible that business will be unable to continue as usual for some of these 'carbon-intensive' industries. Inaction could lead to reduced competitiveness, profitability and viability of these carbon intensive businesses. Some businesses will relocate production to jurisdictions with less stringent environmental legislation to reduce costs. This would significantly undermine the economy of the Tees Valley and North East of England, and the objective of climate mitigation policies.

CCS technology offers the potential for substantial cuts in CO₂ emissions from the power sector and energy intensive industry at affordable cost, globally, in the UK and specifically in the Tees Valley. A parallel engineering study has identified extensive technical potential for CO₂ capture at nearly forty sites in the Tees Valley – densely clustered within a few kilometres of each other. Stakeholders in the region are familiar with CCS technologies and several key emitters consider that they could deploy CO₂ capture facilities in the period 2018-2030.

A range of CO₂ transport options can be developed to various levels of ambition/capacity to connect capture with storage offshore. An integrated pipeline network could transport CO₂ from a range of sources through a common hub and offshore pipeline much more cost-effectively and conveniently than would be the case if each emitter built their own dedicated pipeline. Indeed it is unlikely any point-to-point solution would be economically viable. CO₂ transport by ship is also technically feasible as suitable port facilities exist in the Tees Valley.

UK and European public funding for CCS demonstration provides an early window of opportunity to develop a 'future-proofed' CO₂ pipeline network in the period 2015 to 2020.

Both public and private investors in a CCS network will consider opportunity costs of investment, and will have diverse priorities for investment criteria including:

- Overall economic and strategic benefit (value at risk, replicability, alignment with wider objectives).
- Environmental benefit (i.e. how much CO₂ abatement is likely).
- Costs (e.g. up-front, ongoing, financing costs, costs of service, and the difference between system costs and expected carbon prices).
- Flexibility (e.g. incorporating additional CO₂ supply or connection to alternative storage sites).
- Robustness of investment case (e.g. if utilisation falls below expectations).
- Overall complexity (e.g. planning issues, requirement for regulation).
- The ability of stakeholders to agree on system design and business models and deliver infrastructure in a timely manner.

The most compelling opportunity for strategic infrastructure investment will clearly represent the relative weighting of these factors, so there is no unequivocally best option for the scale of a network. However, the systematic economic analysis and stakeholder engagement carried out in this study suggest that either a 'Small' or 'Medium' scale CCS network at Tees Valley is likely to offer the most value-for-money in terms of strategic infrastructure investment:

The capital requirement for the onshore pipeline network (£10s of millions) falls within the range of typical investments made in infrastructure in Teesside, and could potentially be shared between sources, and phased so that capacity matches demand. Up-front investment in a future-proofed offshore pipeline may add up to £200 million in costs; too large and risky for any single entity to take on, especially on its own balance sheet, whilst the risk presented by low –utilisation and other factors mean it will be particularly difficult to attract significant sums of private finance, especially at commercial rates.

Investment in a CCS network must proceed along a challenging critical path. Important milestones include (i) selection of projects for CCS demonstration; (ii) reaching a final investment decision for anchor projects, sizing of the offshore pipeline and storage strategy; (iii) construction of infrastructure; (iv) sequential connection of emitters to the network; (v) in the long term, handover of the storage site back to the State.

There is a wide range of risks across the life-cycle of a CCS network project in addition to the risks for underlying capture and storage projects. Developers will need to demonstrate that they have taken steps to understand, limit and manage policy, regulatory, technical, market, economic and reputational risks – even those that may occur towards the end of the project life. Failure to address *any* of these issues will likely result in no investment from commercial sources, and would also undermine the case for public investment.

The finance community has considerable experience of structuring finance for pipelines in the oil and gas, waste and water sectors. The key issue is the embryonic of CCS technology, the novelty of commercial arrangements, and the fundamental economic case for investment. Key messages from discussions with capital providers are

- Equity investment will be essential in some form – either through direct investment by companies or through investment into a special purpose vehicle.
- Government support will be critical in providing additional sources of finance and/or in underwriting debt (e.g. as lender of last resort)
- Only the public sector can address some of the key policy, market and regulatory risks.
- Multilateral lending agencies such as the European Investment Bank (EIB) are well positioned to provide financial support to projects, subject to the presentation of a robust business case along the lines of bullets 1-3 above;
- Private debt from project finance houses or infrastructure funds may be available if the conditions outlined bullets 1-3 and/or bullet 4 above are met. This likely to be in limited amounts in the early stages of the technology (e.g. 5-10% of project investment costs), and subject to the robustness of the business case.
- Private equity and venture are not really suitably capitalised and structured to take on investments in CCS at the current time.
- Revenues from CO₂-enhanced oil recovery may improve the viability of the business case, However the oil industry has shown only limited interest in developing this option to date.

Whilst a range of options exist for structuring an investment – including government and single-entity led developments – a Joint Venture special purpose vehicle established by regional operators appears to be the most viable near-term approach for taking the project forward, where:

- The role of the public sector is to provide access to grant funding and reduce policy risks, market risks and regulatory risks across the CCS chain.
- Large power and industrial emitters in the Tees Valley provide equity finance to develop most of the onshore pipeline network and support future-proofing of the offshore pipeline.
- A limited amount of debt finance is obtained e.g. from multilateral lending institutions.
- Initial investments are later refinanced to reduce costs as risks decrease.

To overcome barriers specific to the development of CCS infrastructure in the North East, this report makes a number of recommendations for the One North East (and its successor organisations), NEPIC and local stakeholders who wish to develop further the opportunity to deploy CCS infrastructure. These are listed below:

Recommendation One – Improve organisation of stakeholders in a North East CCS network.

Recognising that regional partnerships in Scotland, Yorkshire, Rotterdam¹, and Northern Netherlands, have been efficient in monitoring, influencing and directing CCS technologies, markets and regulations to the benefit of their regional stakeholders, this report recommends that One North East (and successor organisations) and The North East Process Industries Cluster should seek to establish an appropriate organisational structure to monitor, influence and direct regional CCS deployment most efficiently. The recently formed PICCSI group represents an excellent start in this process.

One option to achieve this is to ensure the Tees Valley becomes a Low Carbon Economic Area for CCS.² Within this structure, the proposed level of organisation could be a 'North East CCS Task Force' and should ideally include:

- Private sector representatives from large existing and potential Tees Valley CO₂ emitters (and medium-sized emitters subject to interest).
- Public sector representatives with responsibilities for spatial and economic planning, climate and energy policy, and the regulatory frameworks for CO₂ capture, transport and storage.
- Potential providers of CO₂ capture, transport and storage facilities. (Oil companies interested in CO₂-EOR could also be included).

Recommendation Two – Use the improved organisation to assist the development of a CCS network.

Recognising that stakeholders will be impacted by international developments in climate, energy and CCS, the Organisation should *evaluate* the local impacts from:

- Global and European energy and climate policies.
- Global and North Sea Basin-related CCS technology and market developments. This would include RD&D, regulations, economics, social acceptance, regional

¹ See for example <http://www.rotterdamclimateinitiative.nl> and <http://microsites.ccsnetwork.eu/rotterdamroad>

² This could provide a means of bringing together formally diver stakeholders that could impact the timing,

initiatives, and health, safety and environmental aspects of CCS system design and operation.

- Legal impediments to commercial discussions between stakeholders and to CCS deployment.
- The ownership, strategies, or activities of key stakeholders and associations.

The Organisation should *influence* :

- The design of European, UK, North East and local policies, regulation and other initiatives for CO₂ capture from the coal, gas and industrial sectors and for CO₂ transport and storage infrastructure.
- Regional and local public and political opinion on CCS
- The priorities of trade associations (e.g. CCSA, CIA).
- The priorities for UK and regional public and private CO₂ storage evaluation
- National planning for energy, CCS and offshore infrastructure

Further the Organisation should seek to act as a single point-of contact to *control* directly:

- Shared responses to Consultations³
- Marketing of a CCS network to wider stakeholders.
- Contractual commitments between stakeholders (e.g. emitters and transport company) to use network if available, to ensure these are compatible with wider objectives.
- The design specification of CO₂ transport and storage infrastructure (capacity, location, entry/exit specifications).
- Engagement with other regional CCS networks (for example in Scotland, Yorkshire and Rotterdam) on issues of common interest.

Any organisation should share lessons with others on stakeholder organisation⁴, risk management and allocation, attracting investment, technical specification⁵, and CCS costs and performance.

Recommendation Three – Provide key stakeholders with an independent, robust assessment of accessible CO₂ storage options.

Recognising that transport and storage costs and risks will depend on the storage site chosen, and that transparency will be critical to obtaining the necessary stakeholder support, this report recommends a continuation of efforts already underway to evaluate accessible CO₂ storage options.

Recommendation Four – Strengthen and support the commercial scale for a CCS anchor project and a CCS network in North East England

Local stakeholders should critically review, strengthen and where appropriate, strongly promote proposals for CCS demonstration projects to be located in the North East of

³ See for example recent electricity market and CCS related consultations listed at <http://www.decc.gov.uk/en/content/cms/consultations/open/open.aspx> , the carbon floor price consultation available at http://www.hm-treasury.gov.uk/consult_carbon_price_support.htm and ongoing updates to national planning policy consultations such as <https://www.energynpsconsultation.decc.gov.uk/docs/ConsultationDocument.pdf>

⁴ See for example Yorkshire Forward's CCS network, Scotland, Rotterdam and the ZEP Task Force.

⁵ As an example, DNV's Pipetrans phase project examines common entry specification for CO₂ pipelines.

England and the overall business case for a CCS network. This will ensure suitable network anchor projects are seen as viable in delivering all the objectives of CCS demonstration *and* have the support of stakeholders making them realistic candidates to nucleate a CCS network.

Recommendation Five – Include CCS within local planning policies

Continue to examine opportunities to reduce costs and barriers through the optimal inclusion of CCS infrastructure requirements within national and local planning policies. This could include updating further the North South Tees Industrial Development Framework to safeguard further potential rights of way identified for potential CO₂ pipelines.

Recommendation Six – Explore public/NGO support for CCS deployment in the Tees Valley

Consider a pilot public/NGO engagement study to understand social drivers and barriers for CCS deployment in Teesside.

Recommendation Seven – Continue to support other options for CO₂ reduction

Recognising that reducing the amount of CO₂ to collect will reduce absolute costs for capture, transport and storage, Tees Valley CO₂ emitters will still need to continue to examine all opportunities for reducing CO₂ emissions and share their forecast emissions where possible.

Recommendation Eight – Examine the impacts of pipeline entry specifications on the costs and feasibility of CO₂ capture and compression for North East emitters and potential storage operations.

Recognising that the entry specification for any transport network may influence capture and storage investments, the Task Force should ensure key stakeholders are fully informed as to the impacts of choices, to ensure system-wide benefits are not threatened. Participation in international programmes would ensure stakeholders are up-to-date with technology development.

If stakeholders decide to push forward with plans to develop CCS infrastructure, a feasible timeline for implementing the steps needed to deliver a joint venture-based approach (coupled to a suitable anchor project) is described below in Figure 19.

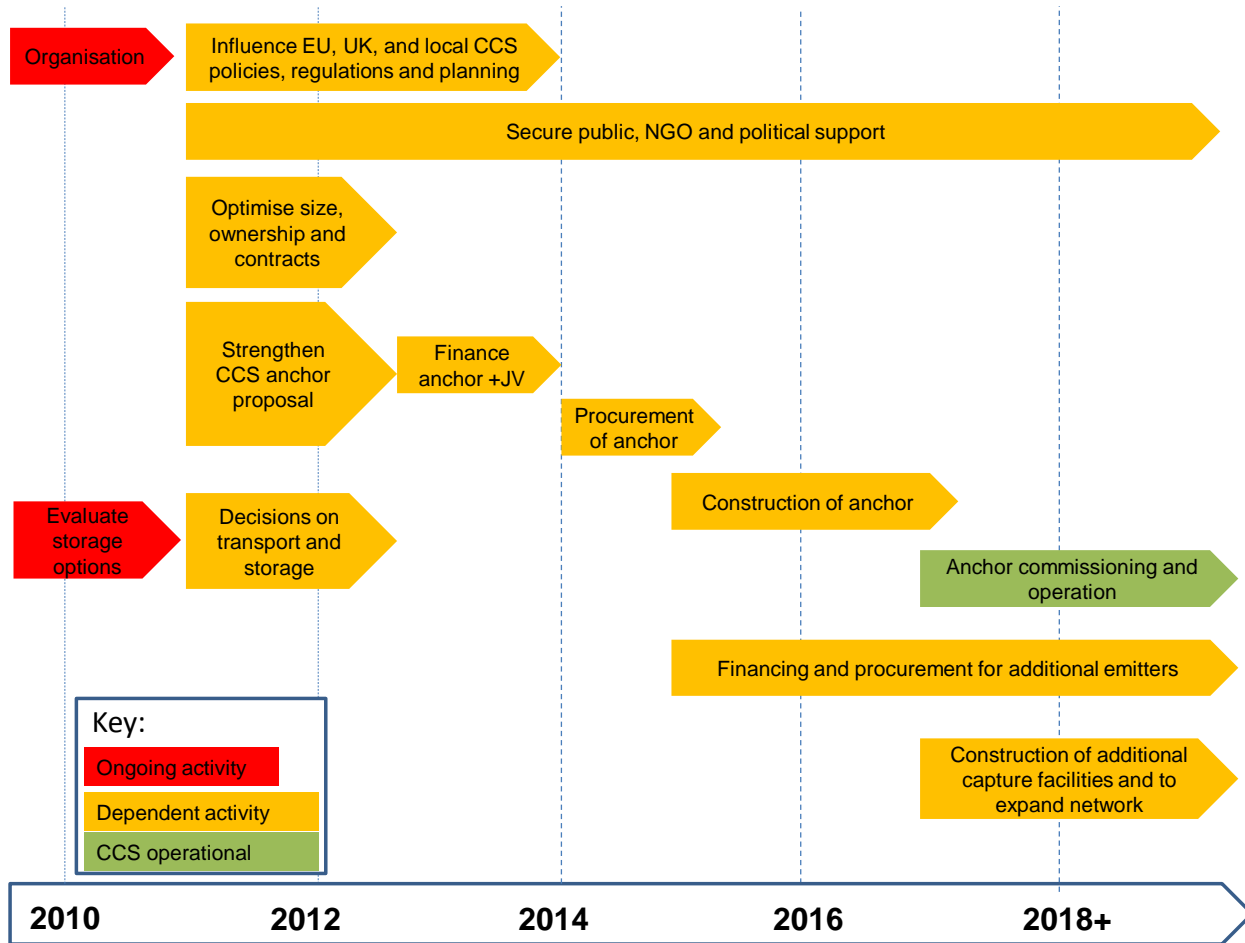


Figure 1 Timeline for potential development of a joint venture for a CCS network in the Tees Valley (coupled to the construction of an 'Anchor' CCS project).

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1 Introduction

This report has been prepared by Element Energy and Carbon Counts on behalf of One North East (ONE). It outlines the results of technical assessment, financial evaluation and the commercial case for potential configurations of a carbon dioxide (CO₂) capture, transport and storage network in the Tees Valley of the North East of England. The focus of the report is on the building of pipeline infrastructure that could collect CO₂ from various sources within the Tees Valley and deliver it to potential geological CO₂ storage sites in the North Sea basin. It reviews the commercial challenges involved, sources of finance and approaches to structuring project development.

The analysis complements a parallel engineering study undertaken by AMEC to evaluate engineering options for building a CO₂ network in the region⁶. Data and engineering options presented herein rely heavily on the AMEC study in order to ensure consistency across the two sets of analysis.

The study has comprised several elements, including

1. Research, building on the team's existing understanding of the low carbon sector and CCS networks in particular.
2. Survey and workshops with local emitters and potential CCS service providers to identify and review inputs, methodology and outputs.
3. Quantitative economic modelling of CCS options.
4. Analysis of risks, risk management approaches, and options for financing and structuring projects.
5. Workshops with the investor and legal community to prioritise concerns and options.
6. Production of interim presentation packs and draft report.

Element Energy and Carbon Counts are very grateful for the views and inputs from the more than forty stakeholders and experts interviewed to gauge their views on various aspects of the potential CCS network.

This final report represents the final and major deliverable from the study, and is structured as follows:

Chapter 2 introduces the challenges facing the UK and Tees Valley businesses in reducing greenhouse gas emissions and carbon dioxide capture and storage technology.

Chapter 3 describes the costs of developing a carbon capture and storage network.

Chapter 4 introduces the risks facing development of a CCS network and approaches to managing this risk.

Chapters 5 and 6 review options for financing and structuring a CCS network respectively.

Chapter 7 presents the key conclusions from the analysis and recommendations for the parties in the North East that wish to pursue further the optimal development of a CCS network.

The report is accompanied by two appendices. Appendix I summarises the results of a stakeholder survey carried out at the start of this project. Appendix II describes the methodology and results of the economic modelling.

⁶ Amec (2010) Engineering Design and Capture Technologies for Carbon Capture and Storage in the Tees Valley. Technical report 1620 1752 Rev A.

2 Setting the Scene

2.1 Tees Valley industry in the North East Economy

The North East of England has an economy worth £40 bn/year, of which £7bn/year arises from manufacturing⁷, wherein more than 40,000 people are directly employed. Within the North East, more than 30,000 people are directly employed in the manufacturing industry in the Tees Valley, an area within the North East that contributes £10/bn per year in Gross Value Added (GVA)⁸.

Initially Tees Valley manufacturing industry was developed on the basis of access to raw materials (coal and iron, and later oil and gas) and world leading delivery (ICI and British Steel). This created a legacy of highly desirable physical infrastructure, workforce, and degree of co-operation between businesses. The Tees Valley remains home to Europe's largest integrated cluster of manufacturing industries⁹, with major proportions of the UK's petrochemical, pharmaceutical, and specialty chemical sectors.¹⁰

Recent investments in the Tees Valley industry exceed £800 million¹¹. Tees Valley contains the world's largest polyethylene plant, the world's largest combined cycle gas turbine heat and power plant, and one of Europe's largest bioethanol plants¹². Proposed investments in the energy engineering sector, worth £8 billion are presently under consideration. Proposals include a heavy oil upgrader, coal gasification, biomass, energy from waste and nuclear power plants, wind turbine construction facilities, and improved port facilities.

Tees Valley process industries are critical to the overall prosperity of the North East and the UK. Recent years have seen inward investment of more than £800m from international businesses and further investments worth several billion pounds are under consideration.

2.2 Value at Risk from CO₂ regulation in the Tees Valley

The reliance of the North East regional economy on manufacturing and process industries make it the most emissions intensive in the UK. Well over half the regions emissions (63%) arise from large industrial sources and power – the highest percentage in the UK – whilst the regions emissions intensity per unit of gross value added (GVA) is double the UK's national rate (767 tCO₂/£million GVA compared to the national figure of 391 tCO₂/£million GVA; Figure 2). This clearly shows that the North East regional economy is particularly exposed to the effects of CO₂ regulation and pricing relative to other parts of the UK.

⁷ ONS(2009) Regional GVA and COE NUTS data available at

http://www.statistics.gov.uk/downloads/theme_economy/NUTS1_A31_GVA_COE.xls

⁸ Tees Valley Unlimited (2010): Local Enterprise Partnership – A proposal; See also ONS (2009) Regional GVA and COE NUTS level 3 data available at

http://www.statistics.gov.uk/downloads/theme_economy/NUTS3.xls

⁹ www.nepic.co.uk

¹⁰ To put these figures into context, the UK is the world's sixth largest manufacturer by output and the chemical process industry sector is the UK's highest exporter with exports in the region of £30bn/year, and 60% of chemical exports originate within the Tees Valley.

¹¹ PB/Genecon (2009) North East Industrial Carbon Emissions – Socio-Economic Analysis

¹² Tees Valley Unlimited (2010) Tees Valley Low Carbon Economic Transition Plan <http://www.teesvalleyunlimited.gov.uk/economyplanning/environment/documents/tees%20valley%20unlimited%20low%20carbon%20economic%20transition%20plan.pdf>

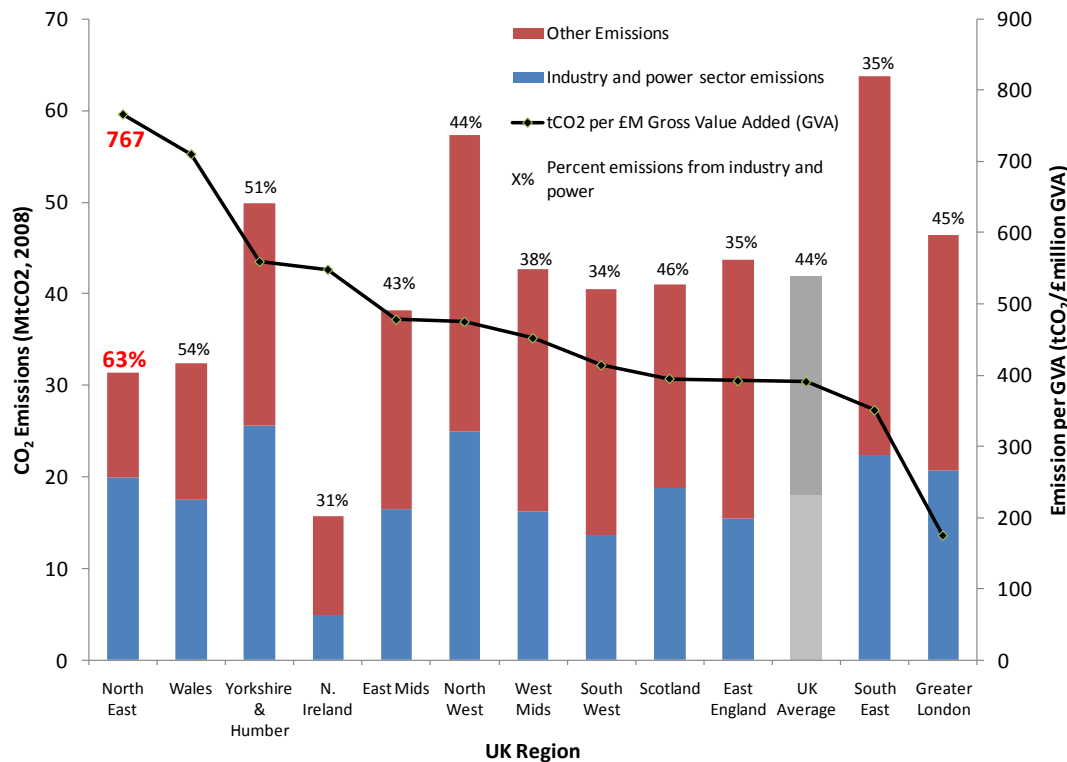


Figure 2 CO₂ emissions and emissions intensity by UK region (2008).¹³

In terms of regulating CO₂ emissions, the UK Climate Change Act sets out a legally binding target of an 80% reduction in CO₂ emissions compared to 1990 levels for 2050, with an interim target of 34% reduction in emissions by 2020.¹⁴ All regions and sectors of the economy will be required to put in place measures to meet these challenging targets, and a range of policy instruments are in place and planned to support the UK Government in meeting its objectives.

For the power sector and heavy industry, the cornerstone of UK policy on CO₂ emissions is the European Union’s (EU) emissions Trading Scheme (EU ETS). The EU ETS is a cap-and-trade framework requires operators of large stationary installations to surrender EU Allowances (equal to one tonne CO₂) each year equal to their reported emissions inventory. Under current arrangements, installation operators have only been required to purchase additional EUAs for the amount of emissions exceeding the free allocation as set by the regulator (the “cap”). The buying and selling of emission rights (EUAs and CERs¹⁵) has led to the development of the nascent carbon market in the EU, leading the

¹³ Based on data from AEA (2010) and Office of National Statistics, GVA by region (2010)

¹⁴ The UK is continuing to develop and implement a raft of energy and climate policies to achieve this objective. This trajectory implies almost full decarbonisation of the power sector by 2030 and significant reductions from the transport, buildings and industrial sectors¹⁴. Policies include financial incentives (such as subsidies for energy efficiency and renewable energy technologies), financial penalties (such as the climate change levy and EU Emissions Trading Scheme), and regulations (such as requirements for new buildings and fossil power stations).

¹⁵ Certified Emission Reductions, which are generated under the Kyoto Protocols clean development mechanism (CDM) for investments in emission reduction technologies in developing countries. CERs can be used as compliance units within the EU ETS, subject to various quantitative and qualitative restrictions set by the EU.

development of a single pan-EU carbon price signal for a range of emitters. Phase III of the EU ETS runs from 2013-2020 and includes some significant modifications compared to previous phases. There will be

- A further reduction in the EU-wide cap, which will reduce annually by 1.7% (subject to reaching an international agreement in the UNFCCC negotiations which could see ambitions go deeper);
- Increased 'auctioning' of EUAs – as opposed to free allocation – to improve the environmental effectiveness and economic efficiency of the scheme.
- Reduced ability to meet EU CO₂ reduction targets by actions outside the EU (i.e. a reduction in the use of CERs, also subject to reaching an international agreement in the UNFCCC negotiations, which could ease these restrictions);
- A requirement to spend at least half of revenues from auctioning to tackling climate change, including the withholding in new entrant reserve and subsequent monetisation of 300 million EUAs to provide support for innovative renewable energy and CCS projects (the NER300);
- Inclusion of various new sectors and gases. For CCS, this means that where CO₂ from a qualifying installation under the EU ETS captures, transports and stores CO₂ in permitted CCS installations, these emissions are subtracted from the installations inventory and the operator is absolved of the responsibility to surrender EUAs for that amount. This is the main form of incentive for CCS under the EU ETS (i.e. an avoided cost or the capacity to sell surplus EUAs, depending on allocation method).

The cost to industry and the power sector from the EU ETS going forward is subject to significant uncertainty as EUA prices are strongly linked to energy prices, economic activity across the EU, as well as uncertainty over the true level of ambition of EU emission reductions due to uncertainty around the UNFCCC negotiations. Private sector average EUA price forecasts lie in the range ca. €19-55/t for the period up to 2020,^{16,17} although others have modelled scenarios in which the CO₂ prices deviate significantly from this range¹⁸.

The cost of compliance with the scheme – both directly through the need to purchase EU emission allowances (EUAs), and indirectly through increasing electricity prices as power generators pass on their EU ETS exposure to consumers – has variable effects on the competitiveness of emitters. Thus, whilst the power sector is generally operating in a regional and/or a national market and therefore has the capacity to pass on the cost to consumers, other industrial activities are involved in the production of goods that are traded in international markets meaning that it is more challenging to pass on these costs. This has led EU industry to raise concerns over its competitiveness in these markets. Further, the issue of 'leakage' has also been raised, a process whereby business shift production to jurisdictions outside of the scheme in order to avoid costs, which could lead to either no net change in global emissions or at worse, a net increase due to a shift to less efficient plant.

¹⁶ See estimates from Deutsche Bank, Barclays Capital, Natixis E&I, New Energy Finance, Societe Generale, Point Carbon Thomson Reuters, Citi Investment Research and Analytics, Daiwa Institute of Research, Euroiean Commission and the CCC itself, all cited in CCC(2010) 2nd Progress Report, available at http://downloads.theccc.org.uk.s3.amazonaws.com/0610/CCC-Progress-Report-web-Chap1_2.pdf.

¹⁷ More recently HM Treasury (2010) *Carbon price floor: support and certainty for low-carbon investment* has identified costs in the range £23-36/tCO₂. See http://www.hm-treasury.gov.uk/d/consult_carbon_price_support_condoc.pdf

¹⁸ See for example http://www.db.com/medienn/en/content/press_releases_2008_3930.htm

A number of research efforts have attempted to evaluate competitiveness and leakage effects on EU industry from CO₂ pricing and identify those sectors that are most exposed. Analysis by the Carbon Trust¹⁹ identified that a number of UK industries are particularly cost-sensitive to carbon pricing. Key sectors affected include:

- Iron and steel
- Refined petroleum products
- Fertilisers and nitrogen compounds
- Aluminium (located at Lynemouth, primarily indirect impact due to higher electricity costs)
- Inorganic chemicals (primarily indirect impact due to higher electricity costs)
- Industrial gases
- Lime and cement (these are not to our knowledge represented in the Tees Valley).

A study undertaken by PB and Genecon concluded that 21 existing energy intensive businesses in the Tees Valley are particularly vulnerable to rising CO₂ prices directly²⁰. Impacts on employment and the regional economy have also been quantified²¹. The exact impacts will depend on (i) rules for allowances for existing emitters²²; (ii) energy and carbon prices; (iii) technology development; (iv) overall trends in industrial activity; (v) ease of relocating production or demand to avoid CO₂ payments or regulations.

As a result, policy-makers have responded to the calls from industry by considering measures to soften the impact for EU industry which is at 'significant risk of carbon leakage'. For sectors deemed to be at significant risk, operators will continue to receive 100% free allocation through Phase III of the EUETS up to a benchmark, set as the top 10 percentile of the most efficient plants in the EU during the period 2007-2008. Sectors deemed not at significant risk of carbon leakage will receive a free allocation of 80% of the benchmark in 2012, reducing to 30% of the benchmark linearly to 2020. Other potential policy measures which have been considered to reduce the risk of carbon leakage include the possibility of introducing border adjustments on imports through taxation, levies or requirements to purchase EUAs at the border according to the CO₂ intensity of products. These options have yet to receive widespread acceptance, and free allocation is the chosen method for the EU through to 2020.

For industries on Teesside that are included in the EU ETS – the power sector aside – all will receive a free allocation in accordance with the rules described above. Based on the allocation process, an estimate of the value at stake for Teesside industry over the Phase III of the EU ETS out to 2020 has been made (Figure 3). This analysis suggests that operators will be exposed to a net loss to the regional income of around £300 million per year, and a total of nearly £2.5 billion over the period 2012-2020.²³

¹⁹ [Carbon Trust \(2008\) EU ETS impacts on profitability and trade.](#)

²⁰ PB/Genecon (2009) North East Industrial Carbon Emissions Socioeconomic Analysis.

²¹ Cambridge Econometrics (2009) The Impact of Climate Change Mitigation Action on the North East Economy

²² Free allocation to existing businesses is called 'grandfathering' of allowances.

²³ This analysis is supported by Cambridge Econometrics (2008) The impact of climate change mitigation action on the North East economy ; N.B. Direct CO₂ emissions from biomass power stations are exempt from the ETS.

Total value at risk, EU ETS Phase III: (2012-20): **£2.5 Bn**

Total Annual Exposure to EU ETS: **£306 M/yr**

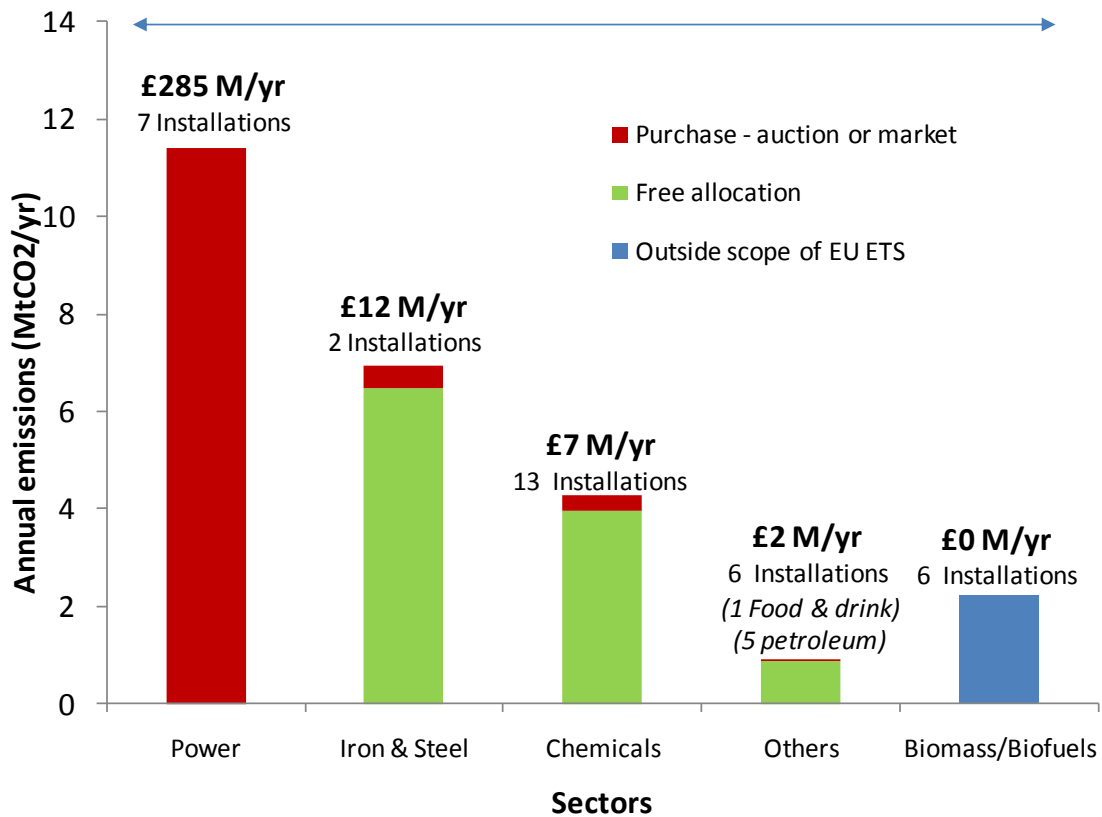


Figure 3 Emissions and value at stake for existing and proposed CO₂ sources in Teesside²⁴.

The Government and most commentators expect the carbon price to rise steeply between 2020 and 2050, as carbon caps are tightened and low cost carbon emission reduction options are exhausted. There remains a wide range in estimates for CO₂ price in all years. Looking ahead twenty years, DECC forecast prices are £35-105/t CO₂ in 2030, rising to £100-£300/t in 2050, whilst it is likely that free allocation will be significantly reduced after Phase III of the EU ETS. Therefore, beyond 2020, the effects of carbon prices will be even more acute.

Payments for compliance with the EU ETS from Teesside operators represent a significant cost burden to business – equal to around 44% of the total GVA of businesses on Teesside. This will likely have significant effects on the competitiveness and profitability of local businesses. If these price effects lead to relocation/carbon leakage, the cessation of these activities would have drastic effects for the local economy.

Presently, around 25 existing carbon intensive businesses on Teesside form the cornerstone of the local economy, employing nearly 7,000 people and adding ca. £700m gross value added each year to the North East economy (Figure 4). Over the period of the EU ETS Phase III (2012-20) the value at risk posed by carbon leakage is around £5.4

²⁴ Sectors based on UK National Allocation Plan classification. Assumes full auctioning for power sector, 100% free allocation to industry (Chemicals, Iron & Steel, Others) with assumed 7% shortfall on benchmark allocation. Bio-emissions outside the scope of the EU ETS, although may in future be eligible for “crediting” if they employ CCS. Carbon price £25/t. CO₂ emissions data taken from parallel AMEC engineering study. Note inclusion of green and blue bars present the potential to monetise EUAs received through free allowances/crediting.

billion²⁵. More than half of these existing jobs are concentrated within the Sembcorp, Sabcic, Lucite, and Tata Steel Europe facilities.

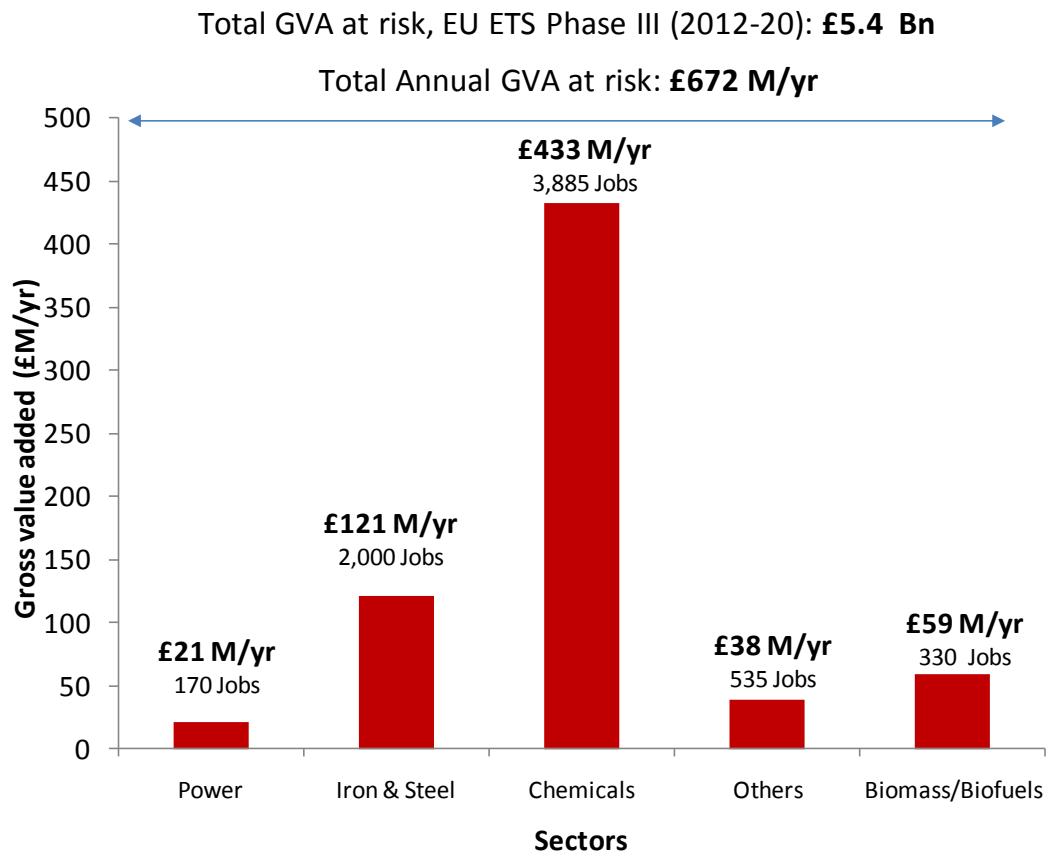


Figure 4 Gross value added at risk in carbon intensive industries in Teesside

If the impacts of CO₂ prices and regulation are not addressed it is unlikely that business will continue as usual for the process industries in the Tees Valley. Inaction will lead to reduced competitiveness, profitability and viability of carbon intensive businesses. Carbon intensive businesses employ ca. 7,000 people and contribute ca. £700m/year to regional GVA. These businesses could relocate to countries with less stringent environmental legislation to reduce costs. This would significantly undermine both the local economy and the objective of climate mitigation policies.

2.3 The need for a step change reduction in CO₂ emissions

Modelling work for the Committee on Climate Change suggests that UK domestic emissions would need to be reduced by 221 Mt CO₂/year between 2010 and 2030²⁶. Of this, most will likely be achieved by decarbonisation of the power sector coupled with efficiency improvements in the building and transport sectors.

²⁵ Undiscounted, assuming constant output. Calculation based on NEPIC estimates of employment and regional GVA multipliers provided by NERIP.

²⁶ Assumes emissions of 471 MtCO₂/year in 2010 and 250 Mt CO₂/year in 2030, based on The CCC (2008) Building a low-carbon economy –the UK’s contribution to tackling climate change.

UK industrial emissions in 2009 were ca. 110 Mt CO₂/year.²⁷ Emission reductions of only ca. 7 Mt CO₂/year can likely be achieved by 2020 through very low cost *incremental* measures such as fuel switching and efficiency improvements in industry, i.e. a small fraction of industrial emissions.²⁸ However, for a *step change* reduction in industrial emissions to occur, and assuming comparable overall manufacturing output in the UK in 2030, other approaches will be required²⁹.

2.4 Global potential for carbon dioxide capture transport and storage

The G8³⁰ and others have identified that a step change in CO₂ emissions reductions in power and industry can be achieved through the deployment of carbon dioxide capture, transport and storage (CCS) technology³¹. CCS involves separating and purifying the CO₂ from one or more sources such power stations, blast furnaces, and chemical plants followed by transportation of the CO₂ to a secure geological formation for injection and long term storage.

Although the process requires additional energy to capture the CO₂, as a carbon abatement measure CCS is expected to be applicable to stationary sources emitting at least 50,000 tCO₂ per year, and cost competitive with other carbon abatement options (including nuclear power and renewable energy-based options).

Although the individual elements of capture, transport and injection have been demonstrated, CCS is still considered to be a technology in the demonstration phase – the principal requirement being to test that an integrated system can operate at a large scale.

The International Energy Agency estimates CCS could deliver 19% of global CO₂ reductions by 2050 - equivalent to 10 Gt CO₂/year, split almost equally among power and industrial/upstream sources³². The corresponding cumulative investment would likely be in the region \$5 trillion. Globally, the cost of meeting 2050 emissions targets is predicted to rise by 70% without CCS.³²

The International Energy Agency's CCS roadmap envisages work commencing on up to 100 CCS projects by 2020, primarily involving coal-fired power plants and low-cost early opportunities; such as high purity CO₂ streams from gas processing and ammonia plants. Consistent with this the G8 has committed to launch the demonstration of up to 20 demonstration plants worldwide by the end of 2010.

²⁷ Combination of indirect and direct emissions, based on The Committee on Climate Change (2010) 2nd Progress Report – Meeting Carbon budgets and ensuring a low carbon recovery. available at http://downloads.theccc.org.uk/0610/pr_meeting_carbon_budgets_chapter3_progress_reducing_emissions_builidings_industry.pdf

²⁸ Data taken from the CCC (2008) Building a Low Carbon Economy, available at <http://www.theccc.org.uk/reports/building-a-low-carbon-economy>. This report also identifies a further 4 Mt CO₂/year saving at up to £40/t that might come from increased deployment of CHP systems. The cost of a syngas network for Teesside is analysed in a parallel study by Amec.

²⁹ Very recently AEA has identified the potential abatement for 2030 from incremental improvement is 18 Mt. AEA (2010) Analysing the opportunities for abatement in major emitting industrial sectors <http://downloads.theccc.org.uk.s3.amazonaws.com/4th%20Budget/Final%20Report%20ED56369.pdf>

³⁰ See for example, http://globalccsinstitute.com/news/media_releases.html

³¹ See for example, <http://www.ipcc-wg3.de/publications/special-reports/special-report-on-carbon-dioxide-capture-and-storage>

³² IEA (2009) Technology Roadmap for Carbon Capture and Storage, available at http://www.iea.org/papers/2009/CCS_Roadmap.pdf

2.5 Potential for CCS in the UK

The UK shares a leading position in support of CCS demonstration. The Government set out its CCS strategy for the power sector in a 'Framework for Clean Coal' in 2008. Building on that policy framework³³, the UK Department for Business, Innovation and Skills and the Department for Energy and Climate Change recently published a strategy for the development of CCS across the UK³⁴. As part of the Strategy, the Office for Carbon Dioxide Capture and Storage (OCCS) has been created to:

- Deliver four CCS demonstration projects based on coal-fired power stations
- Develop models for infrastructure
- Set the longer term strategy and regulatory framework to ensure CCS can be deployed more widely
- Support characterisation of storage sites
- Prepare a roadmap to 2030 coordinating Government and private sector actions

The Strategy highlights an expectation that Teesside will join the Yorkshire and Humber as an example of a Low Carbon Economic Area for CCS.

Recent analysis for the Committee on Climate Change identifies the technical potential for:

- Up to 20 GW coal power (equivalent to 105 Mt CO₂ captured in 2030 based on a load factor of 75%)³⁵
- Up to 30 GW gas power (equivalent to up to 65 Mt CO₂ captured in 2030 based on a load factor of 75%)
- Up to 45 Mt CO₂ captured in 2030 in industry (excluding the power sector)³⁶

Under very favourable conditions, the UK CCS capacity in 2030 could be ca. 60 Mt CO₂ captured/year, rising to ca. 140 Mt CO₂/year in 2050³⁷. It is expected that over the long term, nearly all the CCS potential from UK emitters would be harnessed through shared transport and storage infrastructure to benefit from economies of scale³⁸. The possible value to the UK from CCS could be up to £3bn by 2020 and £6.5 bn by 2030 – equivalent to up to 100,000 high value added jobs³⁹.

³³ http://www.decc.gov.uk/en/content/cms/consultations/clean_coal/clean_coal.aspx

³⁴ http://www.decc.gov.uk/assets/decc/what%20we%20do/uk%20energy%20supply/energy%20mix/carbon%20capture%20and%20storage/1_20100317090007_e_@@_cleancoalindustrialstrategy.pdf

³⁵ Poyry (2009) CCS- milestones to deliver large scale deployment by 2030, available at http://www.ccsassociation.org.uk/docs/2009/504_CCC_CCS%20Final%20Report_v3_0.pdf

³⁶ Element Energy *et al.* (2010) The potential for CCS in gas and industry. Report for the Committee on Climate Change., available at http://downloads.theccc.org.uk.s3.amazonaws.com/0610/pr_supporting_research_element_Energy_CCS_on_gas_and_industry.pdf

³⁷ Element Energy (2010) One North Sea – a study on CO₂ cross-border transport and storage, available at http://nsbtf.squarespace.com/storage/OneNorthSea_FullDoc_Final_LoRes.pdf

³⁸ Element Energy *et al.* (2007) The potential for CO₂ pipeline infrastructure for the UK and Norway, available at <http://nsbtf.squarespace.com/storage/file42476.pdf>

³⁹ DECC (2010) A business strategy for CCS, available at http://www.decc.gov.uk/assets/decc/what%20we%20do/uk%20energy%20supply/energy%20mix/carbon%20capture%20and%20storage/1_20100317090007_e_@@_cleancoalindustrialstrategy.pdf

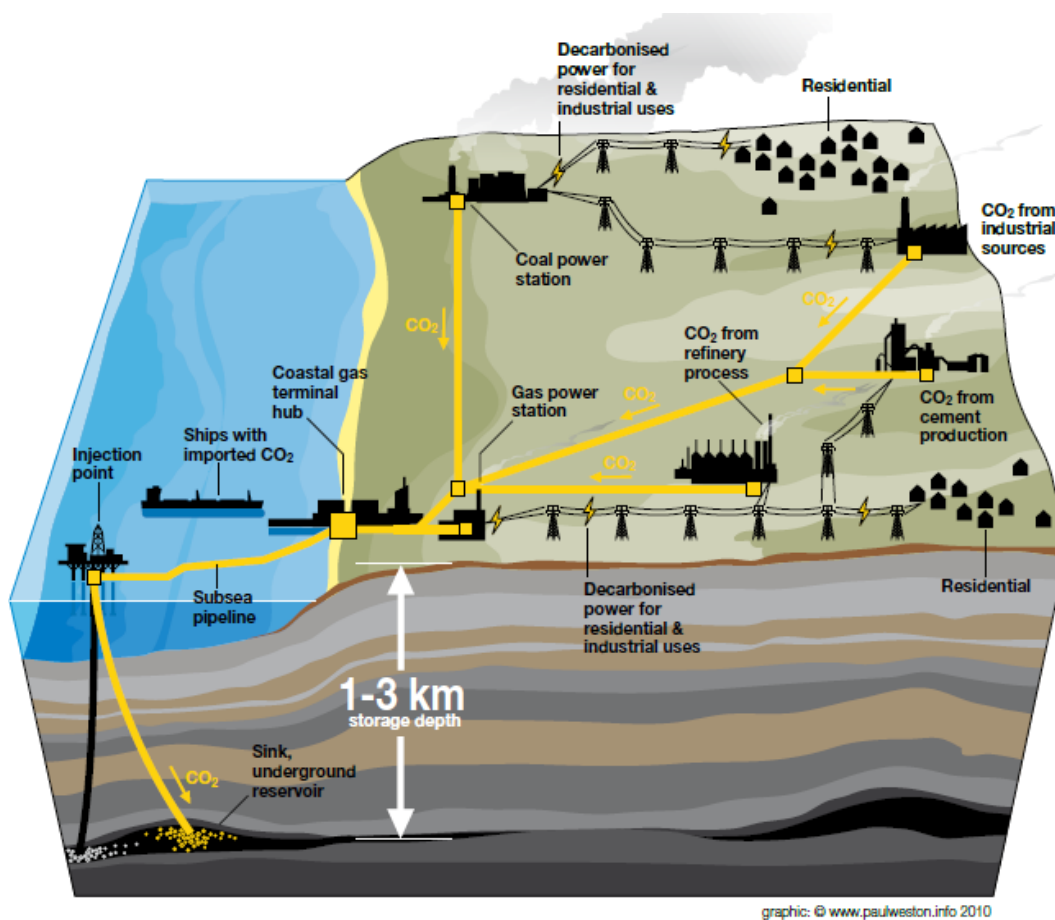


Figure 5 Key elements of CCS are capture (from fossil power stations and industry), pipeline transport and storage deep underground.

2.6 CCS Demonstration: A window of opportunity

In 2007 the UK Government launched a competition to fund demonstration of CCS on a coal power station. Following recent announcements⁴⁰, it is now expected that up to £1bn will be awarded to a consortium comprising Scottish Power, National Grid and Shell for a project comprising ‘post-combustion’ CO₂ capture retrofit at the existing Longannet coal plant in Scotland, transport through an existing gas pipeline to St. Fergus and then offshore to the depleted GoldenEye hydrocarbon field for geological storage.

The previous Government committed to launch a competition by the end of 2010 for three CCS demonstration projects based on coal power stations, to be funded through a levy placed on electricity suppliers, with the purpose of:

- Safeguarding businesses that supply equipment and services for fossil fuelled power generation.
- Developing the CCS supply chain.
- Opening up access to CO₂ storage in the UK Continental Shelf.
- Establishing transport and storage infrastructure to sustain existing and future investment in carbon intensive process industries through the assurance that they

⁴⁰ See <http://www.businessgreen.com/business-green/news/2271862/pulls-uk-ccs-competition> and http://www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/energy_mix/ccs/ccs.aspx

will be able to access a system to handle their CO₂ when the carbon market drives them to CCS.

The Coalition Government that came into power in 2010 completed a 'Market Sounding' Consultation exercise on the future of CCS demonstration shortly after taking office. The Government has announced support for the programme but the scope, source of funding and timescales await clarification.

In addition, the European Union offers financial support for CCS demonstration, to be administered through the European Investment Bank.⁴¹ Projects must be nominated by Member States, and there is an expectation that EU Member States and industry will provide partial funding for CCS demonstration.

2.7 Proposals for CCS projects in the North East

A number of options for CCS projects in the North East have been proposed⁴², including:

- Progressive Energy has proposed an 850 MW IGCC coal power plant at Eston Grange, which could use pre-combustion capture technology.
- Rio Tinto Alcan is considering a 450 MW IGCC coal power plant in Lynemouth.⁴³
- Over the longer term, B9 Coal, a UK based energy company recently announced a proposal to develop a project combining underground coal gasification and fuel cell technologies with CCS. The project could potentially also be situated at the Rio Tinto Alcan facility in Lynemouth.
- GdF Suez's 1.9 GW Teesside gas power station
- The proposed E.On/PX 1 GW Thor gas power station

CCS technology offers the potential for substantial cuts in CO₂ emissions at affordable cost, globally and in the UK. The UK's CCS strategy seeks to capitalise on the existing skills and assets, beginning with demonstration. UK and European public funding for CCS demonstration provides an early window of opportunity to develop CCS infrastructure.

2.8 Building a CO₂ value chain in the North East

If CCS is to be a realistic prospect for deployment in the Teesside region it is critical to consider how a value chain for CO₂ could evolve. The value chain for CO₂ that could drive investments in a CCS network consists of two main components:

⁴¹ Article 10(a) 8 of the revised Emissions Trading Directive 2009/29/EC permits 300 million ETS allowances to be sold on the carbon market and the money raised to be made available to CCS and innovative renewable projects as they operate.

⁴² Joint One North East/PICCSI response to DECC CCS Market Sounding Consultation, available at <http://www.decc.gov.uk/Media/viewfile.ashx?FilePath=What%20we%20do/UK%20energy%20supply/Energy%20mix/Carbon%20capture%20and%20storage/870-CCS-demo-market-sounding-response.zip&filetype=4&minwidth=true>

⁴³ The existing coal power station (dedicated for the aluminium plant) in Lynemouth must be decommissioned as a result of the Large Combustion Plant Directive. Any new build coal plant must follow the UK's Framework for Clean Coal, which stipulates that this must capture a significant proportion of CO₂ output for transport and storage.

Market ‘push’ factors – these relate to economic factors driving emitters to invest in capture plant at their installations. This includes consideration of the value at risk (as highlighted previously), other incentives (such as demonstration project financing), wider Government targets to decarbonise the UK economy, and the capacity of CCS to attract new businesses and investments in the region (such as carbon intensive businesses which face exposures in other parts of the EU absent of a CCS network);

Market ‘pull’ factors – these are more challenging to identify and have not been reviewed in depth within this study. They could include the use of captured CO₂ for enhanced oil recovery (EOR) in the southern Central North Sea, the attendant energy security and tax revenues this could deliver for Government, and strategic interests to North Sea operators to gain experience in offshore EOR and defer the costs of decommissioning North Sea oil & gas infrastructure.

Teesside is in a good position to bring all of these factors into play. CO₂ is already a significant driver for investment decisions for the carbon intensive businesses in the Tees Valley and this is expected to grow in the next five to ten years and beyond.⁴⁴ The value at risk from carbon pricing outlined previously suggests around £8 billion could be at stake in the region to 2020 (Figure 3; Figure 4). A further £1-2 billion could be available from grant financing of CCS demonstration projects from the UK Government and EU funding sources. New inward investment is an unknown quantity, but could be worth several billion out to 2025 if CCS can attract new business.

Furthermore, the technologies involved in CO₂ capture – gas separation, compression and transport – are familiar technologies to many of the large CO₂ emitters on Teesside. Many Teesside operators have access to capital for investment (either because they operate cash generative businesses or have excellent credit ratings) and already operate within challenging health, safety and environmental performance management systems associated with these technologies. Extension to CCS will require a degree of ‘up-skilling’ but is unlikely to require a shift in working culture or practices for those used to working within the chemical/process industries or their regulators.

On the market pull side, if Teesside’s current emissions could be used for EOR, several million barrels of oil per year could be extracted from the Central North Sea, potentially adding up to several billions of pounds to the UK economy, depending on the oil price and project lifetime.

In addition, the region has midstream capabilities to deliver the shared infrastructure that would be needed. Businesses in Teesside already share pipeline infrastructure (for steam, hydrogen, oxygen and wastes), so corporate capacity to develop appropriate contractual structures is already present. This existing institutional capacity could unlock the potential for commercial organisations to own and operate capture, transport and storage infrastructure, without the need for excessive public intervention or oversight. Taken together, these competencies could facilitate CCS deployment in Teesside as and when required.

In the context of a CCS demonstration programme providing one or more ‘Anchor’ projects, a value chain for a CO₂ pipeline network is shown in Figure 6, which highlights market ‘push’ and ‘pull’ factors.

⁴⁴ Result taken from a survey of local stakeholders for this project. See Appendix I

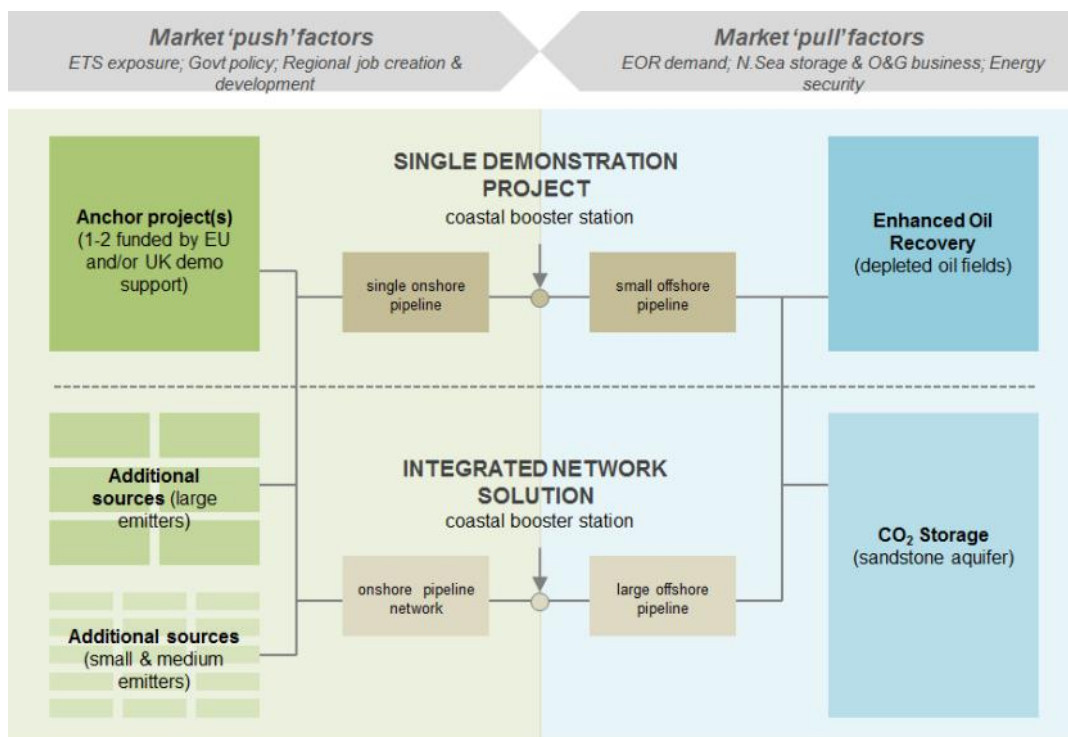


Figure 6 Value chain for CCS comprises sources, transport and storage

The remaining sections of this report consider how such a value chain could evolve in the contexts of:

- Potential configurations for a CO₂ pipeline network to bring together sources and storage sites;
- The levels of capital investment and operating costs that would be involved in building a CCS network in Teesside, at different scales of development;
- The commercial challenges posed by its development; and,
- Options for financing and structuring a vehicle to potentially deliver the required investment.

3 The economics of a CCS pipeline network in the Tees Valley

3.1 Criteria for an optimal CO₂ transport network for the Tees Valley

Whilst a variety of configurations for a CCS network may be possible for Teesside, ranging from just a couple of point sources to a system connecting all emitters for which CCS is technically feasible, there are a range of factors and trade-offs (or key performance indicators) that need to be considered when selecting what an optimised network could look like. Therefore, a balance is required to meet differing objectives, including:

Environmental effectiveness – the most effective option in this case is the network which delivers the deepest reductions in CO₂ emissions (measured in tCO₂ captured or abated/year). This factor is driven by UK, EU and international targets to reduce emissions of CO₂ to the atmosphere. This factor can be measured in terms of the tonnes CO₂ avoided as a result of the network (tCO₂/year).

Cost effectiveness – the most effective option will be one that delivers emission reductions at the lowest unitised cost (measured through £/tCO₂ abated), and in line with the alternative of emitting CO₂ and buying EUAs.

Financeability – a network which requires excessive upfront investment (measured through capex) is unlikely to obtain financing. It has not been possible to place a precise value on this amount, but it will be possible to evaluate different options on a comparative basis and take a view on the likelihood of financing.

System flexibility and stability – for an effective market in CO₂ transportation to exist on Teesside, a degree of liquidity will be required. In this context, the network needs to be able to accommodate capacity reductions and disconnections (due to plant closure, turndowns, mothballing etc.) with the possibility of new entrants into the market. Therefore, a residual pool of potential new connectors would be beneficial to overall network functioning and efficiency. This factor can be measured by the ratio of installations connected and not connected to the network, and the average emissions of installations connected and not connected.

Lead time and phasing – whilst building larger infrastructure can deliver economies of scale, these are not realised if the asset is not fully utilised in early stages. Therefore, the most effective option will be one that minimises the risk of delayed connection in the first few years of operation (measured through the £/tCO₂ transported under different scenarios of demand).

A range of other more qualitative factors also need to be taken into account, including system complexity and deliverability.

3.2 Opportunities for CO₂ capture in the North East

In a parallel engineering study, the possible CO₂ supply for a CCS network in Teesside has been quantified as likely to fall within the range 5-26 Mt CO₂/year. The lower estimate would assume only one CO₂ emitter is connected, whereas the larger figure would essentially be a theoretical maximum, corresponding to capture from 37 point sources.

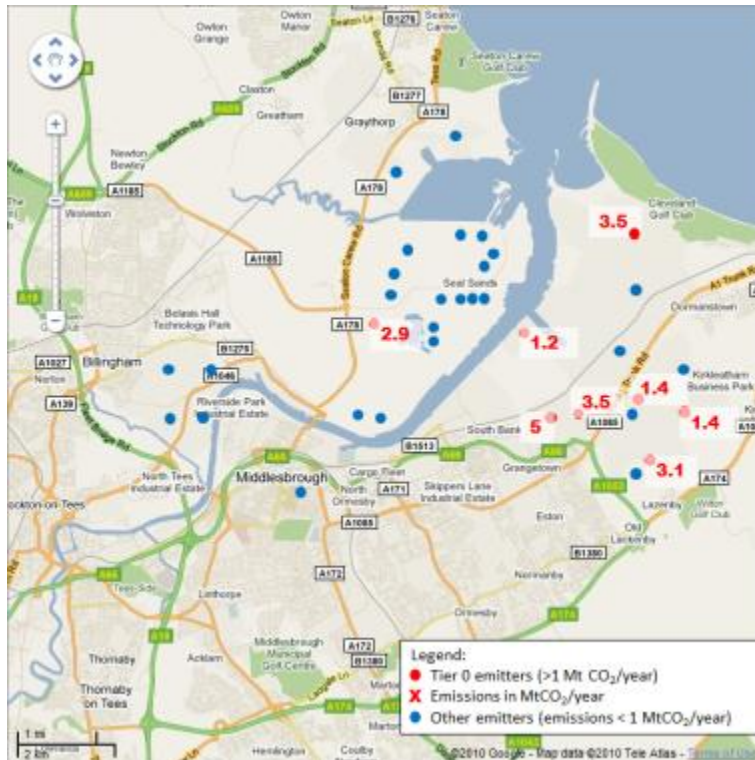


Figure 7 High density of large (red circles) and medium (blue circles) existing and potential CO₂ emitters in the Tees Valley.

Additional emitters in the North East such as the proposed Rio Tinto Alcan replacement coal power station in Lynemouth could potentially supply an additional 5 MtCO₂/year.

3.3 Cost-effectiveness of CO₂ capture in the Tees Valley

The dominant cost for a CCS system is in capture⁴⁵. The capture costs can be divided into:

- **capital** costs of equipment for initial CO₂ separation, purification and compression
- **ongoing** costs for operation, maintenance and the additional energy required to operate the capture process.

Capture costs can be conveniently represented in terms of £/tCO₂ captured or £/tCO₂ avoided (or 'abated'), the latter format corrects for abatement efficiency of the capture process⁴⁶. The cost of CO₂ capture is expected to come down over the next two decades through research, development, demonstration and through large scale deployment. The rate of cost reduction for CCS is however particularly difficult to predict in the heterogeneous industrial sector.

Following discussions with stakeholders, four illustrative scenarios allow different levels of CCS uptake in the Tees Valley.⁴⁷

⁴⁵ See for example, McKinsey (2008) CCS – assessing the economics.

⁴⁶ The capture process requires some energy to separate the CO₂ from other gases and compress to high pressure for pipeline transport or liquefy for transport by ship. Costs and CO₂ estimates are derived from the parallel engineering study led by Amec. See Appendix 2

⁴⁷ The input scenarios reflect differences in the scale of CCS adoption in the Tees Valley, they do not reflect the outcome of any analysis of macro-economic or micro-economic drivers in the Tees Valley.

- An ‘Anchor only’ or point-to-point system (here the cost is modelled as incremental cost of fitting CO₂ capture facilities on the proposed Progressive Energy IGCC plant at Eston Grange).
- A ‘Small’ system, (here modelled as including the existing and planned sources >1 MtCO₂/year but excluding the existing Tata Steel Europe steelworks sites (currently mothballed) and MGT biomass site (exempt from the ETS)).
- A ‘Medium’ system (here modelled as including all existing and planned sources >1 MtCO₂/year).
- A ‘Large’ system with all the sources above 50 ktCO₂/year in the Tees Valley for which CCS is considered technically feasible.

Importantly, capture costs benefit from economies of scale, so that inclusion of large volumes of CO₂ at low CO₂ cost at Teesside of £36/t CO₂, CCS is cost competitive with the deployment of, for example onshore wind, and considerably more competitive than some other renewable energy technologies.⁴⁸

Table 1 Economics of CO₂ capture in the Tees Valley⁴⁹

Description	Anchor only	Small	Medium	Large
No. of point sources	1	5	8	35
Annual CO ₂ captured (Mt CO ₂ /year)	5	14	22	26
Lifetime CO ₂ avoided (20 years)	83 Mt	262 Mt	377 Mt	434 Mt
Incremental capital cost of capture and compression	£151 m ⁵⁰	£1.1 bn	£2.0 bn	£3.1 bn
Incremental operating and energy costs for capture and compression of CO ₂	£55 m/yr	£187 m/yr	£298 m/yr	£371 m/yr
Mean average £/tCO ₂ captured	£15	£21	£24	£30
Mean average £/tCO ₂ abated	£18	£25	£29	£36

⁴⁸For example public support for microgeneration technologies can be measured at up to £1,000/t CO₂ avoided.

⁴⁹Based on cost of service for 20 years, assuming cost of capital is 10%. Refers to incremental cost of fitting capture facilities within a new IGCC power station. See Appendix for details.

⁵⁰Incremental cost relative to an IGCC plant only, see for example NETL (2007) Cost and Performance Baseline for Fossil Energy Plants – Volume 1: Bituminous coal and natural gas to electricity final report DOE/NETL-2007/1281 Available at <http://www.netl.doe.gov/energy-analyses/pubs/deskreference/index.html>

3.4 The economics of CO₂ storage

The Tees Valley is competitively placed with access to all major storage options in the North Sea including depleted gas fields, depleted oil fields, saline aquifers and injection into partially depleted oilfields with the goal of enhancing oil recovery (CO₂-EOR)⁵¹. In the UK sector of the North Sea there is a theoretical storage potential of up to 69,000 MtCO₂, with considerably higher levels of CO₂ storage available in other sectors⁵².

Previous source-sink matching exercises have shown that the combined theoretical storage capacity of sinks within a realistic pipeline distance (e.g. 200 km) from Teesside is sufficient to accommodate several decades' worth of Tees Valley industrial and power sector emissions⁵². Given considerable uncertainty over specific sinks or types, the risks of investment are reduced through opportunities to screen a number of stores of different types.

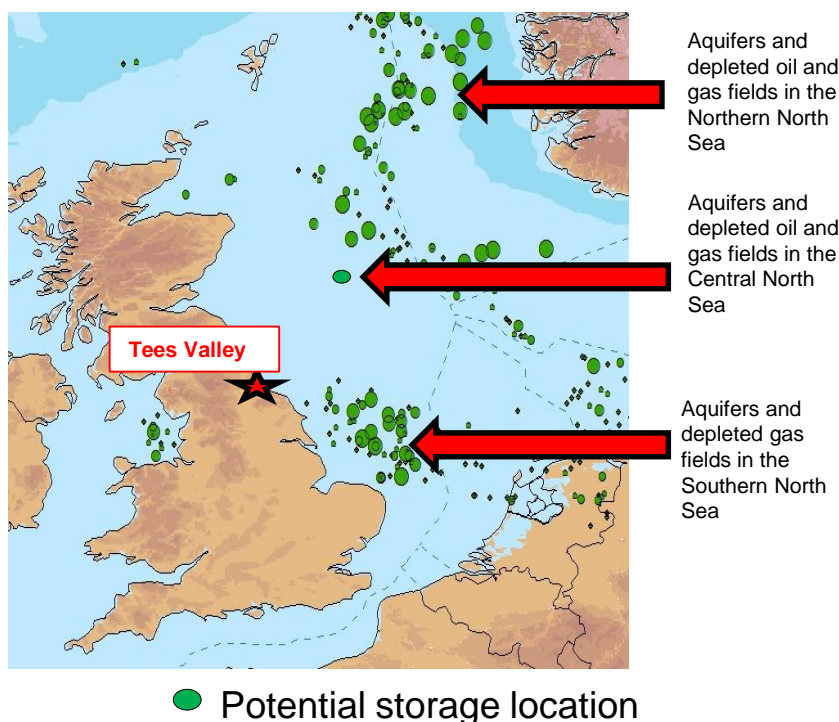


Figure 8 Proximity of diverse storage options (green circles) in the North Sea.⁵³

Working with One North East and Progressive Energy, the British Geological Survey, Scottish Centre for Carbon Storage and Durham University have already invested considerable effort in characterising relevant North Sea storage options⁵⁴. Infrastructure requirements will depend on the precise location and a detailed subsurface model.

In the absence of access to a detailed reservoir model of the chosen storage site, a high level cost analysis, described in the appendix provides indicative storage costs of £12/t for

⁵¹ Element Energy (2007) Potential for North Sea CO₂ pipeline infrastructure for the UK and Norway, on behalf of the North Sea Basin Task Force.

⁵² Element Energy (2010) One North Sea study, on behalf of the North Sea Basin Task Force.

⁵³ Data taken from Element Energy (2010) One North Sea (available at <http://www.element-energy.co.uk/sectors/carbonCaptureStorage/OneNorthSea.pdf>) and One North East (2010) Carbon Capture and Storage in North East England – A prospectus.

⁵⁴ One North East (2010) Carbon Capture and Storage in North East England – A prospectus, available at <http://www.onenortheast.co.uk/lib/liReport/15938/carbon%20capture%2032pp%20A4%207%20aw%20web.pdf>.

the Medium and Large networks (including costs of financing but excluding initial site development fees)⁵⁵. The “Anchor-only” system⁵⁶ has cheaper absolute capital and operating costs, but is slightly higher on a unit cost basis – see Table 2.

For the Medium network, a sensitivity analysis reveals that in a ‘best case’ scenario, the cost of storage could fall to £ 2.3/tCO₂ stored (See Appendix 2).

Studies of the economics of CO₂-EOR have typically concluded that oil prices would need to be sustained in excess of \$70/barrel for CO₂-EOR in the North Sea to be cost competitive with CO₂ storage alone⁵⁷. However the economics will depend strongly on site specific issues, technology developments, taxation and incentives, and the whether CO₂ supplied represents a cost or a revenue source.

Table 2 Costs of CO₂ storage⁵⁸

Scenario Description	Anchor only	Small network	Medium network	Large network
Capex for injection facilities and wells (£m)	£153 m	£322 m	£463 m	£560 m
Opex for injection facilities and wells (£m)	£6 m/yr	£15 m/yr	£20 m/yr	£22 m/yr
Storage cost £/t CO ₂ stored	£14/t	£13/t	£12/t	£12/t

Storage costs and risks may be reduced and the development of storage infrastructure accelerated through shared analysis. The Yorkshire Forward CCS community has indicated it is open to such an approach.⁵⁹

⁵⁵ This assumes a water depth of 100-150 m and reservoir depth of 2km. Storage cost modelling is described in the appendix.

⁵⁶ An anchor project could be one of the proposed single source CCS demonstration projects. In principle this could be a new build or retrofit, from the power sector or industry. In this study the ‘anchor’ has been modelled with emission characteristics similar to the proposed Eston Grange IGCC project although alternatives are possible.

⁵⁷ Scottish Centre for Carbon Storage and Scottish Government (2009) Opportunities for CO₂ storage around Scotland - An integrated strategic research study, available at <http://www.geos.ed.ac.uk/sccs/regional-study/CO2-JointStudy-Full.pdf>

⁵⁸ Cost refers to new injection facilities, wells and monitoring only. Assumes an injection rate of 1 Mt CO₂/year/well with an average monitoring cost of £1/t. Weighted average cost of capital assumed is 10%. A review of the potential for future-proofing storage options was out of the scope of the present study.

⁵⁹ S. Brown (2010) *Personal communication*

3.5 Options for CO₂ transport

3.5.1 Onshore

Seventeen high pressure pipeline transport networks for Teesside have been modelled in a parallel engineering study, differentiated by which CO₂ sources are included. The parallel study finds that CO₂ pipeline routes connecting nearly all major sources are technically feasible⁶⁰. The majority of large emitters are clustered together in South Tees. A tunnel under the Tees could offer connection to the sources on the North Tees.

These four network options are illustrated below:

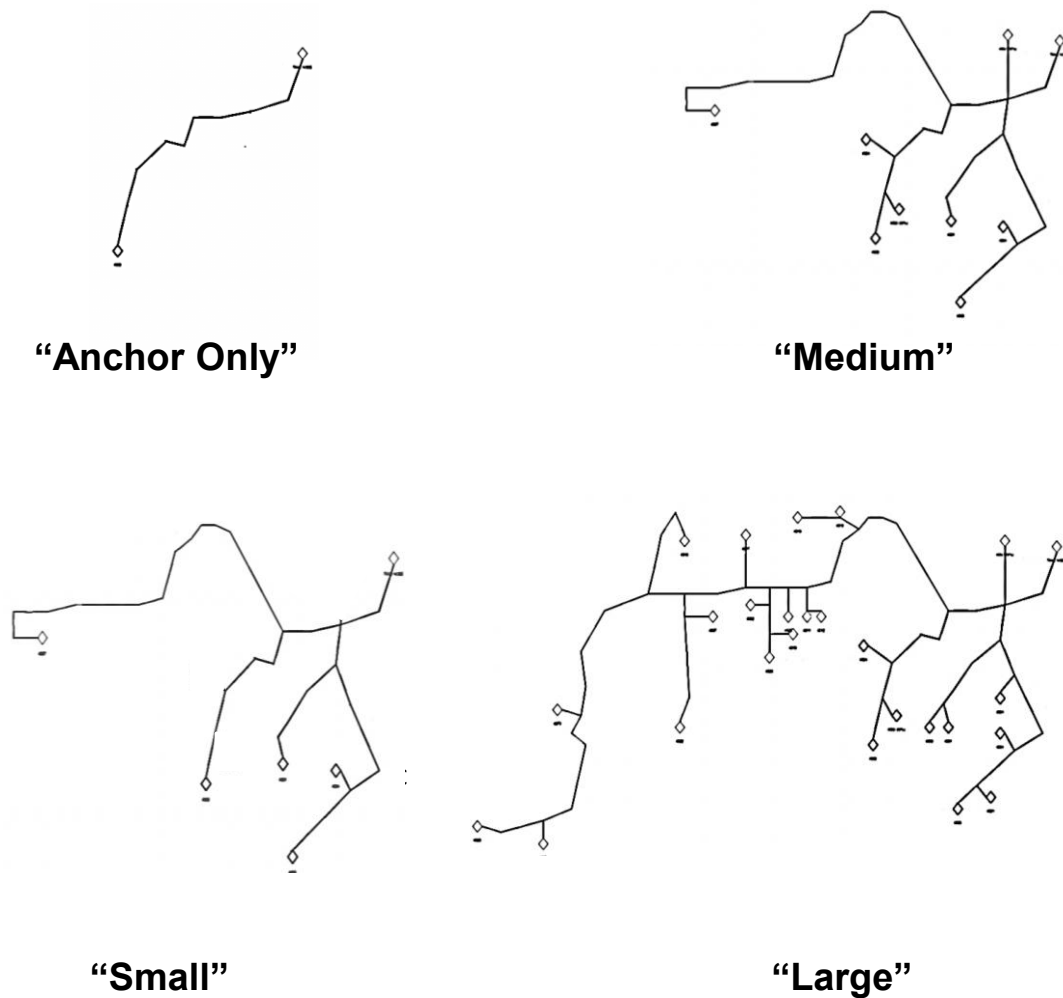


Figure 9 Schematic of ‘Anchor-only’, ‘Small’, ‘Medium’, and ‘Large’ onshore network options.

⁶⁰ This is subject to constraints that may be imposed by the UK Health and Safety Executive for the operation of high pressure CO₂ pipelines in the UK.

Table 3 Description of onshore transport networks

Network description	Anchor-only	Small	Medium	Large
Number of sources	1	5	8	37
Peak capacity (Mt/yr)	5	14	22	26
Onshore pipeline distance	5 km	19 km	22 km	37 km
Capital cost for onshore pipeline(s)	£7.5 m	£46 m	£48 m	£60 m

3.5.2 Offshore pipeline

Choices for the offshore pipeline will depend *inter alia* on routing issues, and engineering judgements on the potential for line pack, flexibility, stress management, availability of wall thicknesses, and vulnerability to incidental damage offshore. Larger diameter pipelines minimise pressure drops, which may make operation easier to manage.

For this report, the following assumptions are used, taken from interim outputs from the parallel engineering study⁶¹.

⁶¹ See Appendix.

Table 4 The costs of the offshore CO₂ pipeline (200 km from Tees Valley to the North Sea) and combined network (inclusive of owners costs and rights-of-way).

Network description	Anchor-only	Small	Medium	Large
Network physical capacity	5 Mt CO ₂ /yr	14 Mt CO ₂ /yr	22 Mt CO ₂ /yr	26 Mt CO ₂ /yr
Modelled diameter offshore (for 200 km length)	500 mm (20")	600 mm (24")	900 mm (36")	900 mm (36")
Capital cost for offshore pipelines ⁶²	£333 m	£365 m	£485 m	£485 m
Combined capital cost for network (onshore and offshore pipelines and shoreline compression)	£346 m	£425 m	£546 m	£562 m
Additional capital cost for network compared to anchor/demonstration only	£0	£79 m	£201 m	£216 m
Cost of service (assuming users pay equally for access) ⁶³	£12/t	£7.3/t	£7.4/t	£7.4/t

The emitters on Teesside form a dense cluster of sources, so that distances for the onshore network are small. Even a “Large” scenario for onshore CO₂ pipeline network in the Tees Valley has a capital cost of £60 m and combined pipeline length of only 76 km.⁶⁴

Small distances, the opportunities to use brownfield land, a favourable planning regime⁶⁵, and a coastal location may significantly accelerate pipeline permitting relative to deep inland onshore sites where proximity to residential areas or use of greenfield land may become significant hurdles.

The offshore pipeline cost increases with its length and diameter. The length relates to the distance to storage site, plus any necessary routing correction. Large diameter pipelines open the potential for transport of large volumes of CO₂, without the need for excessive compression.⁶⁶

⁶² Includes owners costs and rights-of-way.

⁶³ Assumes 20 year economic lifetime, 10% weighted average cost of capital.

⁶⁴ The onshore distance compares very favourably with that for the proposed CO₂ pipeline infrastructure for the Yorkshire and Humber region.

⁶⁵ See <http://www.teesvalleyunlimited.gov.uk/economyplanningenvironment/documents/north%20and%20south%20tees%20industrial%20development%20framework.pdf> for example

⁶⁶ A range of possible offshore pipeline diameters can be modelled – see Appendix for details.

Table 4 identifies the economies of scale or higher capital efficiency of investment in the 'Medium' network compared to the 'Anchor' network. Thus for an additional up-front investment of £201 m it is possible to increase capacity from 5 to 22 Mt/yr.

Assuming a simple cost recovery model, the cost of service for users of the network will need to cover:

- Capital and operating costs for the onshore pipelines.
- Capital and operating costs for the offshore pipeline.
- Capital, operating and energy costs for shoreline compression.
- The costs of financing.

Table 4 identifies the cost of service for the different CO₂ networks, based on a flat rate charging model.⁶⁷

3.5.3 CO₂ transport by ship

The deep-water port provides flexibility in offshore CO₂ transport infrastructure. Assuming excess pipeline and storage capacity is accessible by pipeline from the Tees Valley, the port facilitates ease of CO₂ import by ship from other regions of the UK and Europe which may not have convenient access to safe storage sites⁶⁸.

The Tees Valley already has a history of ship transport of CO₂ for use in the food and drinks sector. Shipping can be cost competitive with pipelines for small volumes. With lead times for CO₂ ships expected to be two to three years, individual ships can be ordered to meet demand, which means capacity and utilisation can be matched more closely than for pipelines⁶⁹. An analysis of the economics of CO₂ transport by ship was out of the scope of the present study.

3.5.4 Lead times and phasing of CO₂ transport network economics

Like other investments in low carbon infrastructure, CCS infrastructure development is associated with long lead times. Even an anchor only CCS system will have a critical path involving several elements, each of which may take one or more years:

- Storage site evaluation
- Clarification of policy, legal, regulatory and economic conditions
- Detailed engineering design
- Permitting
- Procurement and financing
- Construction (could take three or four years)
- Commissioning

Whilst some of these steps could occur in parallel, even if a decision is made by the public sector to support CCS in the North East, it may take between five and seven years for a demonstration project to be fully operational. Addition of subsequent projects will be policy

⁶⁷ A range of alternative tariff structures can be modelled.

⁶⁸ The proposed Fortum/TVO project intends to transport CO₂ from the Meri Pori coal-fired power plant in Finland to the North Sea by ship, and the use of shipping has been highlighted within the Rotterdam Climate Initiative.

⁶⁹ In the event of non-utilisation, ships can be redeployed elsewhere in the world for CO₂ or LPG transport, and therefore present a contrasting risk profile to pipelines where investment is highly specific.

driven in the period to 2020 – these would therefore reflect public priorities for CCS development.

For a Medium or Large network, initial infrastructure financing will require additional time, as may development of capture technologies for specific emitters. The timeline assumes steady rather than simultaneous connection of other large emitters. A market survey carried out during the project identifies that a number of businesses could anticipate connection to a CCS network in the period 2020-2030. From this survey response, the recent CCC study on application of CCS in the gas and industry sectors, and conversations with stakeholders, fast, medium and slow estimates of a technically realistic CCS adoption rates were developed. Medium development rates for each of the four scenarios are presented in Figure 10 and are used as a baseline for the analysis of the economics of the transport network.⁷⁰

With a few exceptions from sources which already produce fairly pure streams of CO₂, most of the small emitters (below 1 MtCO₂/year) are unlikely to consider connecting to a CCS network (if at all) before 2030.

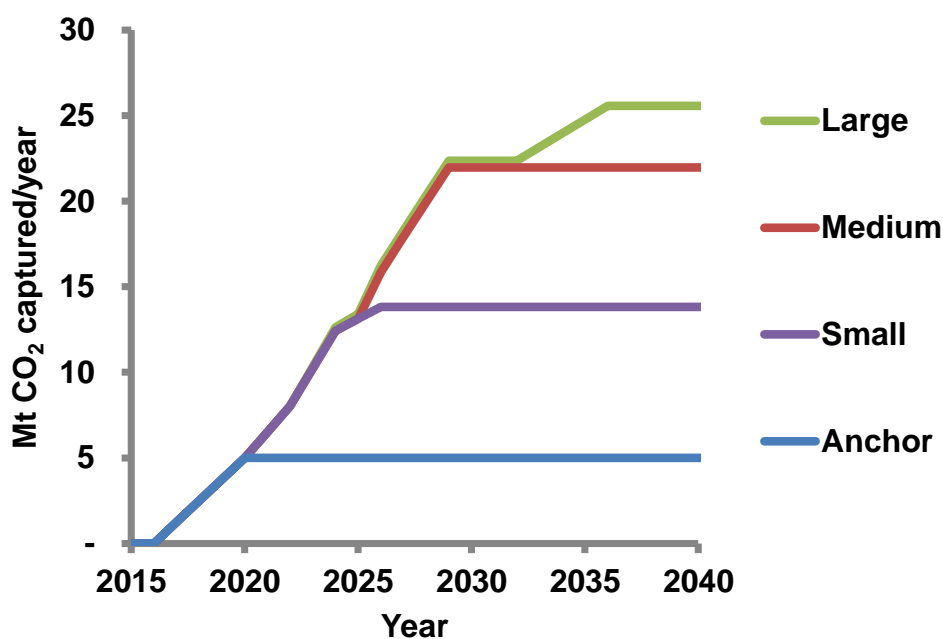


Figure 10 Baseline CCS uptake scenarios for Teesside

A CCS system capturing 22 Mt CO₂/year (i.e. abating 18 Mt CO₂/year)⁷¹ could deliver 8% of the abatement in 2030.⁷²

⁷⁰ Following discussions with stakeholders a three year period is assumed for optimising the CCS system (to reach full utilisation – see Appendix 2).

⁷¹ Assumes 26 Mt CO₂/year captured with an abatement efficiency of 84%.

⁷² To put these figures into context, a recent report for the Committee on Climate Change determined that the use of 16 million electric vehicles in the UK could provide a CO₂ saving of between 5 and 16 Mt CO₂/year in 2030. (Element Energy (2010).

Drawing on the above analysis and drawing on stakeholder consultation, a range of sensitivities for CCS deployment have been modelled for each scenario to understand the impacts from different phasing of connections i.e. utilisation of different networks⁷³.

The higher the utilisation of the network, the lower the average cost per user, as fixed costs are shared more widely. This is illustrated in Figure 11 for a 'Medium' CCS network. Figure 11 also shows that the cost of service is highly sensitive to the discount rate (or weighted average cost of capital). Networks funded with high cost of capital are particularly sensitive to reduced utilisation (shown in Figure 11 as the position where the cost of service exceeds £10/t). The economic modelling shows that where networks are funded with a cost of capital of 5% (i.e. where public finance is likely to be the dominant source of capital), then an eleven year delay can be tolerated between the first and subsequent emitters joining⁷⁴.

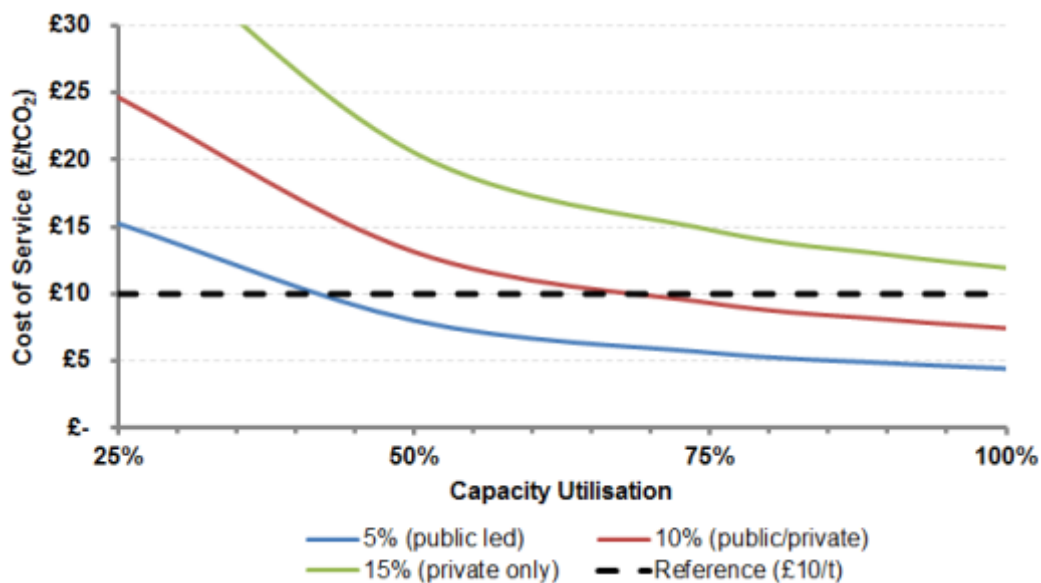


Figure 11 Interplay of % utilisation and % discount rate on cost of service of Tees Valley Medium CCS network.

The full sensitivity analysis includes:

- Reduced utilisation (modelled as 50% of projected emissions, either because some sites fail to adopt CCS or adopt CCS but provide lower CO₂ supply because of efficiency improvements)
- Delayed utilisation (for example if it takes an additional five years for CCS technology to be adopted by other sources in the Tees Valley)
- Delays in construction, so that this takes five years instead of three years.
- Onerous financial obligations, for example short payback times (10 years) or high weighted average cost of capital (15%).

The analysis also considered potential benefits to the network economics that might arise from

⁷³ See Appendix II

⁷⁴ If the weighted average cost of capital is 10% and emitters join in two waves, only four years delay can be tolerated. If the cost of capital is 15%, then less than one year delay between emitters can be tolerated.

- Provision of demonstration funding for an anchor project, so that remaining emitters pay only the *marginal* costs of the pipeline instead of the average costs.
- Stable regulatory and market environment and publicly-backed financial arrangements that allow access to long payback times (e.g. 40 years), low weighted average cost of capital (e.g. 5%).

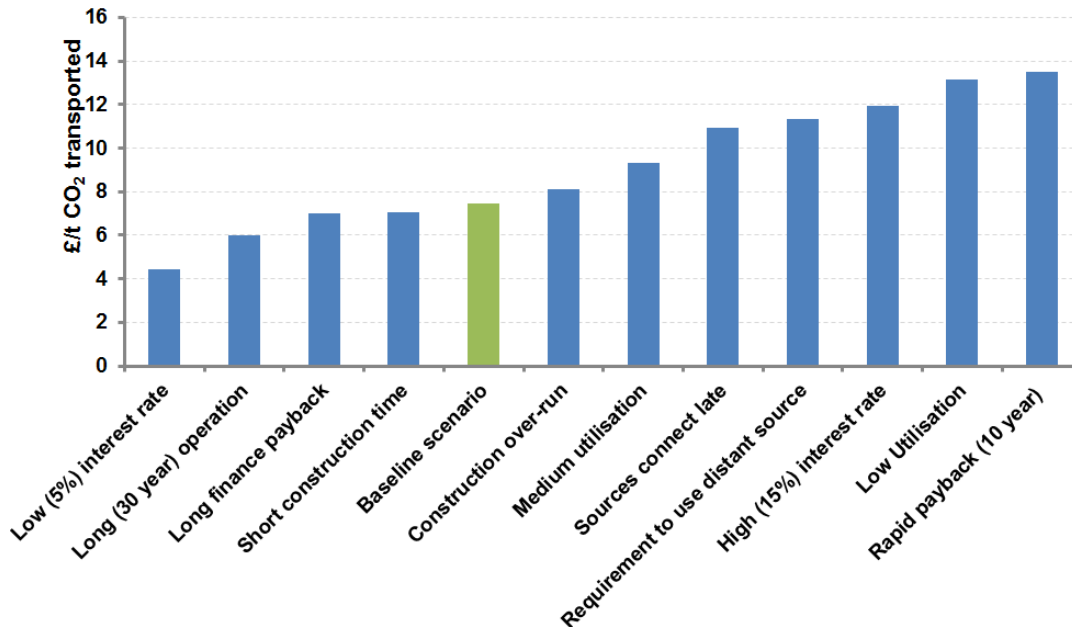


Figure 12 Cost of service of investment in offshore CO₂ pipeline infrastructure compared to baseline scenario.

The impacts on these sensitivities on the cost of service for the ‘Medium’ transport network are shown above (Figure 12, baseline scenario shown in green). The actual cost of service clearly depends on a range of inter-related factors. Use of nearby sinks, favourable financing conditions and early connections of subsequent sources could each reduce network cost of service below £5/t CO₂. In contrast, reduced utilisation, long offshore pipelines or high risk premia could each drive cost of service above £10/t CO₂. The analysis identifies that the network could remain economic with up to an eleven year delay between the first and subsequent sources connecting.

Combinations of these factors would obviously have a more profound impact on overall economics than individual factors alone. For example, a combination of expensive finance, low utilisation and delays in sources connecting would result in excessive tariffs for users that would not be economic for any of the networks modelled in this study even at carbon prices above £60/tCO₂.

3.6 Comparison of system costs and performance

The average abatement cost of a ‘Medium’ sized CCS system connecting eight point sources is estimated at ca. £48/t CO₂ abated inclusive of financing (see Table 5). Of this,

£7/t CO₂ is expected as a cost of service for use of a common transport network with a maximum transported capacity of 22 Mt CO₂/year. Table 5 presents a comparison of the network options against the criteria introduced previously.

Table 5 System performance criteria⁷⁵

Description	Metric	Anchor Only	Small	Medium	Large
Environmental effectiveness	MtCO ₂ /yr captured	5	14	22	26
Financeability	Combined capex for capture, transport and storage	£650 m	£1.8 bn	£3.0 bn	£4.2 bn
Cost effectiveness	Average capture cost £/tCO ₂ abated	£18	£25	£29	£36
	Transport £/t CO ₂	£12	£7.30	£7.40	£7.40
	Storage £/t CO ₂	£14	£13	£12	£12
	Total £/tCO ₂ abated	£44	£45	£48	£55
Flexibility and stability	Ratio of sites capturing CO ₂ : sites not capturing	1:35	5:30	8:27	35:0
	Ratio of CO ₂ emissions captured: emissions not captured	5:21	14:12	22:4	26:0
Lead time / complexity	Number of sources connecting	1	5	8	35

In addition to a system-wide perspective, which averages costs, individual emitters will be keen to understand their own costs for implementing CCS. The marginal abatement cost curve (Figure 13) below shows the CO₂ abatement potential from individual sites, ordered

⁷⁵ See Appendix for further details.

in terms of increasing costs of service for full CCS (i.e. capture, transport and storage).⁷⁶ In Figure 13 each segment corresponds to an individual source. The height of each bar reflects the unit cost assuming an integrated transport and storage network, whereas the width refers to the CO₂ saving. The area of an individual bar corresponds to the lifetime net present cost for CCS for that emitter.

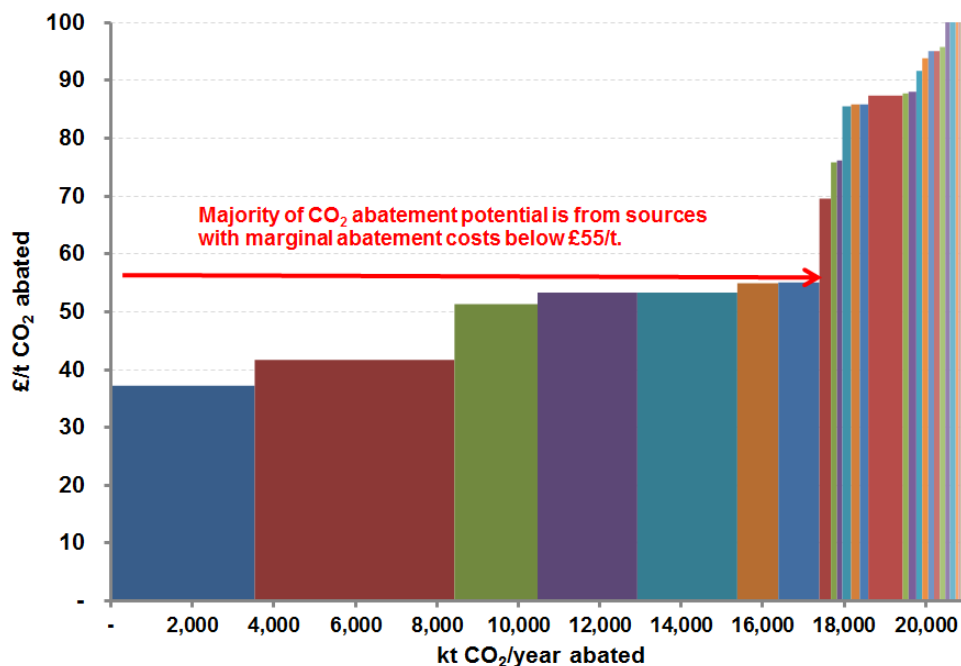


Figure 13 CCS marginal abatement cost curve for a ‘Large’ network of emitters in the Tees Valley. Each bar corresponds to an individual emitter connected to a common transport and storage network.

Within the context of potentially large errors associated with estimates for the costs and CO₂ volumes that might be relevant in the period up to and beyond 2030, the shape of the marginal abatement cost curve shows that both CO₂ volumes decrease and costs increase gradually, with a step rise in costs occurring only after 7 sources are connected. Since the CCS costs are comparable to the wide range of expected CO₂ prices between 2020 and 2030, it could be commercially viable to capture from all or none of the plants in the Tees Valley based on the difference between the CCS price and the carbon price.⁷⁷

3.7 Conclusions on economic case for investment in CCS networks

Assuming investors are minded to invest in developing CCS infrastructure, the decision on which transport network to pursue will reflect a trade-off between the priorities described in Section 3.1.

⁷⁶ The names of individual emitters have been withheld to protect commercial confidentiality agreements.

⁷⁷ If the cost of CCS or CO₂ is not borne by competing industries, then even if CCS is cheaper than the EUA price it may still be unaffordable for individual business units. W. Jones (2010) *Personal communication*

Considering pipelines only, the decision should be pivoted around the design of the offshore pipeline as this will be the largest single expenditure. In terms of the degree and timing of CO₂ emissions reduction, a network sized solely for an anchor project offers the most limited CO₂ abatement potential. Subsequent projects would each need to develop their own transport solution which would raise the costs and delay implementation. Conversely the Large network offers the potential for the highest CO₂ emissions reduction of CCS as the most emitters could connect to the network. The Small and Medium networks offer compromise options with intermediate levels of CO₂ transport.

The variable operating costs of a CO₂ pipeline are very, low, so that costs are dominated by the capital cost and fixed operating costs. These costs are essentially directly proportional to the distance from the shoreline to sink. The absolute costs of a single anchor project are the lowest of any of the networks, but the costs of repeating the investment in the offshore pipeline suggest that this approach would be very expensive in absolute terms. Investing in the large network would incur the highest absolute up-front costs and operating costs. Clearly the Small and Medium networks offer compromise options with intermediate levels of capital required.

It is difficult to see how a pipeline for an anchor project only (or several point-to-point pipelines) could ever be commercially viable, other than in the specific context of CCS demonstration, as the cost of service for the pipeline would need to be around £12/tCO₂.

Under a 'baseline' scenario, which assumes a discount rate of 10% and economic lifetime of 20 years, and where utilisation of the network grows gradually from 2018 to 2030, the Small, Medium and Large networks would need to charge an average cost of service of around £7.4/tCO₂ to ensure economic viability. However, expectations of value for money (in terms of £/tCO₂) are highly sensitive to discount rate (or weighted average cost of capital) and utilisation assumptions. The higher the discount rate, the more likely the investor would need to be confident that the pipeline would be used at full capacity quickly.

In terms of flexibility, there are three important considerations. The first is that the diameter of a pipeline is fixed and limits flexibility by limiting the maximum CO₂ transport capacity. Under this definition, the 'Large' network obviously provides the most flexibility for future sources to connect. The second is that any pipeline is a highly specific investment. Not only is it unlikely that a CO₂ pipeline would be readily re-used for any other purpose, but the precise location inherently dictates which stores are economically accessible. As an example, if the pipeline is built initially directed to the saline aquifers or depleted gasfields in the Southern North Sea, it would be expensive later to develop a spur to connect to oilfields in the Central and Northern North Sea to participate in CO₂-enhanced oil recovery. The third consideration is the potential flexibility to accommodate different CO₂ specifications (composition, temperature, pressure etc.). Although the transport of CO₂ by pipeline is in any case likely to be highly restricted to very narrow conditions of impurities, it is nevertheless technically possible that a series of point-to-point pipelines could each have slightly different CO₂ specifications (instead of an integrated network which would necessarily have the most restrictive entry conditions).

In terms of robustness and investment risk, the principle risk here is of low utilisation, which is exacerbated when the network is built in anticipation of future sources connecting, unlike a point-to-point or Anchor only system where pipeline investment would be expected to be fully coupled to investment in capture. The investment risk is highest therefore for the largest network, so that Medium and Small networks may provide sensible compromises if uncertainties are considered too high.

The Large network offers the highest potential to safeguard or grow the Tees Valley economy, as it will likely be able to provide capacity to all the carbon intensive businesses. However it also provides the most complexity and therefore in the current climate would have the lowest chance of delivery. Given the current immaturity of CCS technology, most investors would consider it unrealistic to plan today for a system with up to 37 potential connectors. Certainly it is unlikely that co-ordination and joint investment could be delivered at this stage.

Figure 14 shows the total capital expenditure for a CCS system ranges from ca. £650 m (for the Anchor only system) through to £4.2 bn for the Large system. Figure 14 also shows the breakdown in capital expenditure for the different networks into capture (including compression), pipeline transport, and offshore storage. Compared to the absolute capital cost of capture, which increases considerably with network scale, and dominate the small, medium and large CCS systems, the costs for the transport network increase more slowly with capacity.

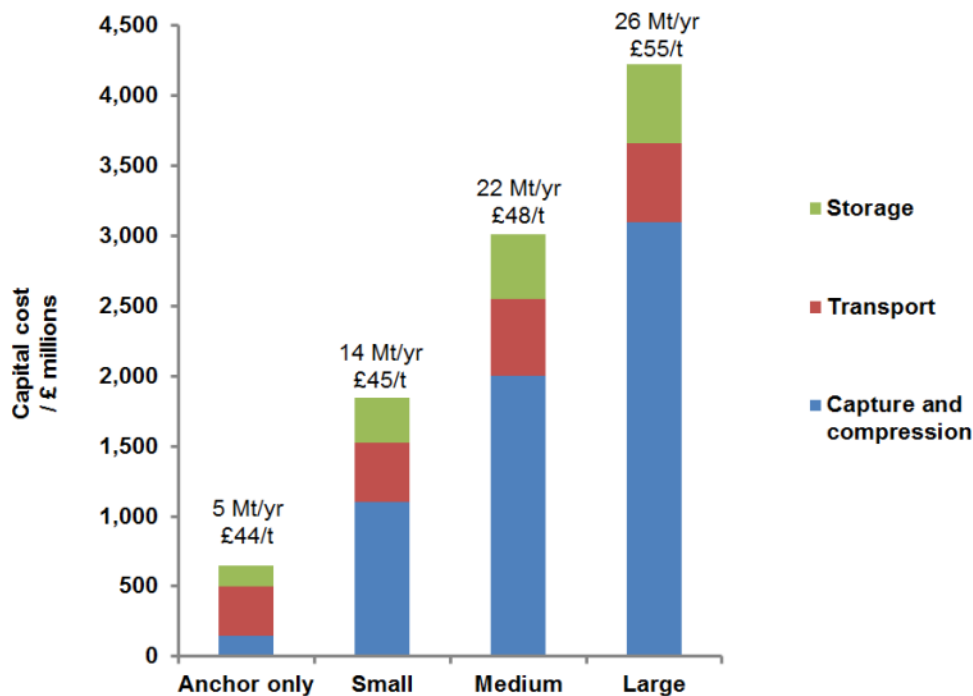


Figure 14 Capital outlay for the four Tees Valley CCS network scenarios. Peak capacities (Mt/yr) and average system £/t CO₂ abated costs are also shown.

Of the pipeline options, the Small or Medium network would therefore appear to present a realistic compromise in balancing economic, energy and climate objectives.

Modelling of the economics of CO₂ transport by ship was out of scope of the present study. Ship transport is expected to have higher operating costs but may be particularly advantageous for investors with very low risk appetite – as it allows for capacity to be added incrementally as the network grows. Subject to potential constraints in unloading CO₂ offshore (not explored here), shipping may provide the most flexibility in choice of storage site. However, if a decision is subsequently made to transport CO₂ by pipeline, this could necessitate two rounds of expenditure in transport infrastructure.

The Tees Valley provides a competitive location for CCS infrastructure deployment.

- 37 potential capture sites are concentrated in a small geographic area in the Tees Valley and are responsible for the majority of the North East's CO₂ emissions.
- The Tees Valley has access to a wide range of geological storage options in the North Sea with theoretical capacity sufficient to meet demand from Tees Valley power and industrial for several decades.
- Cost-effective integrated pipeline transport networks can service demand for CCS – it is unlikely that any point-to-point offshore pipeline solution could develop, other than solely for CCS demonstration, as it would be uneconomic.
- Shipping and enhanced oil recovery represent additional enablers for CCS infrastructure in Teesside.
- A realistic timeline for CCS adoption envisages one demonstration project in the Tees Valley which is operational before 2018, joined by other large emitters throughout the period to 2030. Small emitters might join after 2030.
- The capital investment required for a large CCS network is estimated ca. £4.2 bn. This compares favourably with exposure to the ETS (£2.5 bn) and value at risk (£5.4 bn) in the period 2012-2020.

4 Identifying and managing the risks

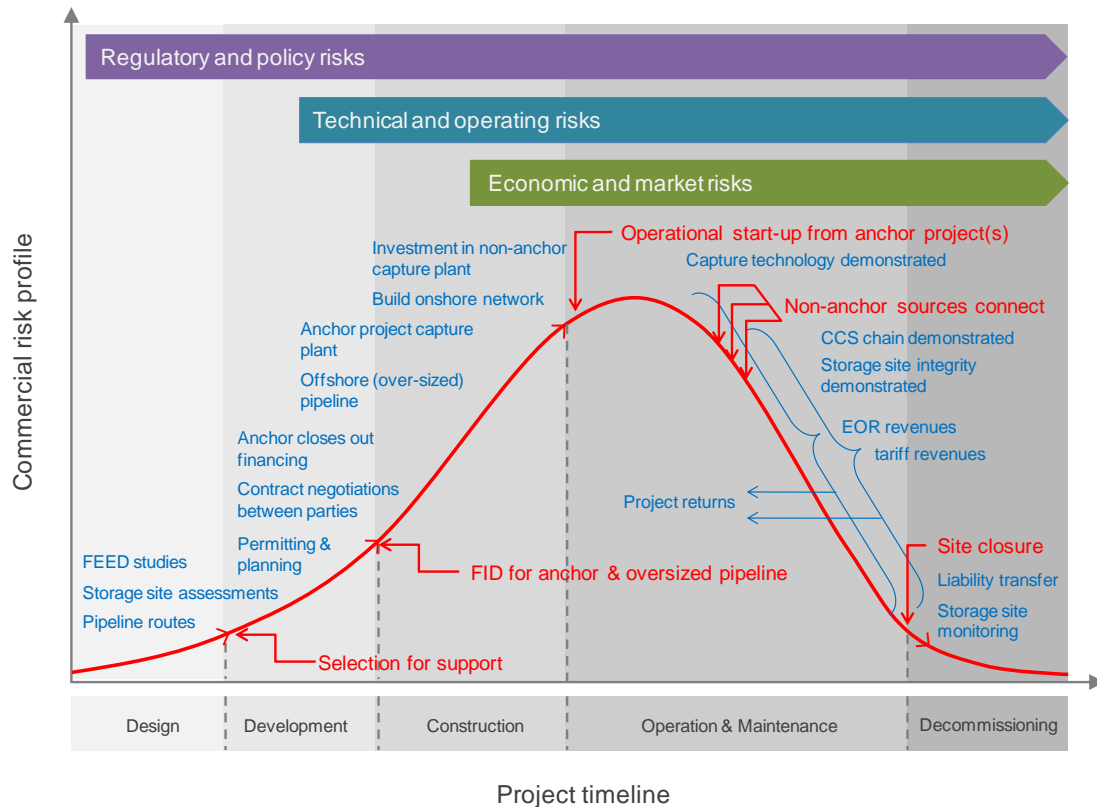
The potential benefits associated with building and successfully operating a large-scale CCS network are accompanied by larger project risks and challenges relative to an already challenging 'point-to-point' CCS solution. Some of these challenges are common to developing any integrated CCS project at scale in the current demonstration phase; others arise from the additional issues associated with building a scaled-up network involving a larger number and variety of counterparties, larger capital requirements, and the added complexity in coordinating the actions - including phased development over time - required between all players in the CCS value chain.

These factors pose material risks which need to be understood and managed to levels comparable with other successful or potential investments. They also clearly influence how potential lenders view investing in a CCS network and, in view of the challenges, the suitability of different sources of project finance.

An assessment of the key project risks and challenges, the approaches to managing them, will inform the most likely appropriate sources of finance the most suitable range of options for the commercial structure and ownership of a CCS network for Teesside. These options are explored in the next section (Section 6).

4.1 Risks through the project life cycle

Figure 15 illustrates that the scale and types of commercial risk associated with a CCS network vary across the CCS project cycle, from the design and development stages through to full network operation and finally decommissioning.



Note: project timeline and level of commercial risk are illustrative only (not to scale)

Figure 15 Commercial risks across the project lifecycle

The key project milestones are also shown in Figure 15 in red, and include:

1. Selection of anchor project(s) for EU and/or UK CCS demonstration support
2. Reaching a final investment decision (FID) for the anchor project(s) and over-sizing of the offshore pipeline
3. Operational start-up from the anchor project(s) i.e. CO₂ capture, transport and storage of the anchor project emissions
4. Connection of other industrial emitters into the network
5. Site closure and decommissioning

Clearly a much larger range of project milestones and decision points also need to be reached by the full range of parties involved across the project value chain (some of which are shown on Figure 15 in blue text).

Progress through the project cycle requires successful transitions between each project phases and decision-based milestone. For example, without a FID being made on the anchor project(s), an onshore network for the purposes of subsequent connectors cannot

be financed⁷⁸. Each party will have its own set of key decision points, contingent upon those of the other parties involved.

Figure 15 also demonstrates how the commercial risk profile of the project as a whole increases as the project moves from the design and development stages (£10s of millions) through to the construction of plant and network infrastructure (£100s of millions). Once the network is built and the CCS chain is successfully demonstrated, the commercial risk profile is then reduced, subject to a range of factors - including capital providers achieving their required return on investment through cost recovery (see Section 6 for a discussion of revenue model options).

The levels of commercial risk associated with the onshore and offshore investment components differ. For example:

- The capital requirement for the onshore network is in the order of £10s of millions and falls within the range of typical on-balance sheet capital investments made by a large corporate, particularly as this could be a shared cost among connecting sources.
- Building the onshore network can be phased as different tranches of sources connect, thereby limiting the commercial risk exposure of the infrastructure as a whole, and allowing individual branches to be funded by the main beneficiaries.
- The up-front investment in the 'over-sized' offshore pipeline represents the largest infrastructure capital requirement (several £100s of millions), thereby exposing lenders to the most substantial level of commercial risk - most noticeably associated with under-utilisation.

From a technical and engineering viewpoint the pipeline may be deemed to present the least risk within the entire CCS chain. However the commercial success of the transport element is contingent on multiple individual 'projects' i.e. capture, compression and storage. The value chain requirements for an integrated CCS network see these complex risks overlaid several times over.

As shown in Figure 15, specific risks arising across the project cycle can be broadly grouped into regulatory, policy, technical, operating, economic and market risk categories, each of which impacts the overall commercial risk of the project as a whole. Where multiple parties are involved in developing a project on a commercial basis, the specific risks need to be allocated across counterparties to those most suited to accept and manage them, and negotiated such that the adoption of risk is balanced with potential rewards (for example, the developer/operator of the over-sized offshore pipeline might offset its significant investment risk by ensuring 'cost plus' recovery through network-user tariffs and/or EOR revenues).

Aside from establishing a robust business case, there is an absolute requirement for project sponsors and developers to demonstrate to lenders, project supporters and other stakeholders that all risks have been understood and can be adequately managed ahead of project commencement.

⁷⁸ Similarly, potential investment in EOR activities (tertiary production from North Sea oil fields) is likely to be contingent upon demonstration of a predictable and steady flow of CO₂ volumes above a certain level.

Investment in a CCS network must proceed along a challenging critical path. Important milestones include (i) selection of projects for CCS demonstration; (ii) reaching a final investment decision for anchor projects, sizing of the offshore pipeline and storage strategy; (iii) construction of infrastructure; (iv) sequential connection of emitters to the network; (v) eventual handover of the storage site back to the State.

The capital requirement for the onshore pipeline network falls within the range of typical investments made in infrastructure in the Tees Valley, can be shared and phased so that capacity matches demand.

Up-front investment in an initially ‘over-sized’ offshore pipeline may add up to £200 million in costs, exposing lenders to significant commercial risk, particularly from low utilisation.

The interconnectedness of the different components and parties across the CCS network creates ‘project-on-project’ risks that will need to be managed *before* any investments are made.

4.2 Economic and market risks

Numerous risks may impact the fundamental economic performance of the network as a whole, and also the separate investments made within it across the project cycle. Traditional project finance, whether based upon debt or equity - or various combinations and forms of both - requires a robust business model rooted on a thorough understanding of all costs (capital and operating expenditure) and income streams (up-front or performance-related grants, financial incentives, revenues) arising throughout the entire project cycle (the “cash-flow” model).

Many of these elements are subject to significant uncertainties outside the direct control of the network developer/operator, investors and potential users. Some are macro-economic in nature, influenced by international or national market factors; others are project-specific and intimately linked to the technical and operational performance of the CCS network and its constituent components. These uncertainties however need to be factored into any analysis providing the basis for decisions made in relation to capital lending and corporate investment.

Key economic and market risks associated with the project include:

- **Cost overruns.** CCS has high capital costs and a variety of unforeseen technical and engineering factors that could result in significant cost (and time) overruns, leading to greater lending requirements and therefore potentially reduced project returns to asset owners and capital providers. Cost overruns could apply across the project chain (capture plant, pipeline infrastructure, storage site facilities) at the start, during operation⁷⁹, or on decommissioning.
- **Carbon prices within the EU ETS.** In the absence of policy instruments such as carbon price floors or contract for differences (CfD)⁸⁰, investors will be subject to the

⁷⁹ Under-performance e.g. reduced efficiency of capture or need for additional storage infrastructure could lead to higher costs during operation.

⁸⁰ Just prior to publication of this report, the Government has announced that it will consult on providing certainty through a carbon floor price. HM Treasury and HMRC (2010) Carbon price floor: support and certainty for low carbon investment, available at http://www.hm-treasury.gov.uk/d/consult_carbon_price_support_condoc.pdf

market volatility of EU Allowance prices. EU Allowance prices since the start of the EU ETS have been too low to incentivise large-scale CCS; the market volatility adds further commercial risk exposure to project investors. Carbon price risk has been identified by industrial stakeholders as the main challenge to investing in capture plant on Teesside (see Appendix I).

- **Energy price increases.** Because capture and compression require energy, increases in electricity and fossil fuel prices may add to project costs. Oil price changes will particularly impact projects connected involving CO₂-EOR.
- **Sector-specific cost risks.** Each industrial and power emitter faces different cost structures and production/market characteristics to their on-going commercial operation. A variety of cost and market factors could therefore impact ‘business as usual’ plant operation and result in non-connection, or reduced supply throughout the network lifetime, thereby impacting upon other parties and the commercial viability of the CCS network as a whole.
- **Currency risk** –common to many infrastructure projects and readily manageable.

‘First movers’ face an additional commercial risk, so called ‘pre-investment risks’ leading up to final investment decisions being made by key project sponsors, for example non-recovery of costs in the event of a failure to attract initial investment. Up-front commercial risks borne by project sponsors and developers must be balanced by mutually acceptable rewards within the structure and ownership of the network project. This is explored further in Section 6.

Cost overrun, carbon prices, energy prices, currency exchange rates, and enhanced oil recovery will influence the economics of any CCS network. In addition, each emitter will be exposed to sector-specific and business-specific economic and market risks that will drive their decision as to whether to install capture facilities. Pre-investment expenditure is unlikely to be recoverable in the event the project fails to attract full investment.

4.3 Regulatory and policy risks

Policy and regulatory uncertainty create uncertainties in future revenues, project design requirements, project approvals/licensing and liabilities, and is identified as a key barrier to capture plant investment on Teesside (see stakeholder analysis, Appendix I).

The primary source of revenue envisaged by the EU and UK Government for CCS projects is through the off-setting of EU Allowance purchase costs for qualifying installations that employ CCS i.e. an avoided cost (see Section 2.2). However, future compliance costs within the European carbon market is extremely uncertain, and there is general consensus that in the near-term, EU Allowance prices will not reach a level sufficient to offset abatement costs associated with CCS⁸⁰.

The immature nature of the carbon market, its policy- and regulatory-driven nature, its linkage to primary energy prices, and strong price relationship with EU economic output all make for a rather unstable system upon which commercial organisations must make billion pound plus investment decisions, especially for a ‘first of a kind’ technology such as CCS. Indeed given the likely timescales for construction and operation of a CCS network, the uncertainties regarding the ETS present an overriding risk for project developers and

lenders. **At the current time therefore, the EU carbon market should only be viewed as a support mechanism for CCS acting in conjunction with other supplementary measures.**

In this context, two sources funds currently exist to support CCS demonstration on Teesside - the EU New Entrant Reserve (NER) of 300 million EU Allowances set aside for support of CCS and novel renewable technologies, and the UK CCS demonstration funding an additional three projects. Notwithstanding the emergence of these various support mechanisms, they are principally geared up to cover only the *incremental* cost of CCS and/or feasibility assessments - significant amounts of private capital will still be required to bring any underlying green-field projects forward. However, the economics and commercial viability of the underlying projects will also be affected by the CCS part of the project, potentially making these projects more difficult to fund e.g. the effect of CCS on power price, especially where the plant competes with unabated coal- or gas-fired power generation.

The modalities for the disbursement of funds are also subject to uncertainty, and issues such as *ex post* adjustment of the amount of finance allocated add to the present mix of policy uncertainty. Despite the attention accorded to CCS at both the EU and UK level, it is becoming apparent that the level of public financial support - both currently provided, and expected from future support schemes - means that private finance will be required to help deploy CCS at scale in the UK, a view supported by UK Ministers at the current time (see Box 1).

Other specific regulatory and policy risks include the following:

- **Uncertain CCS policy and support⁸¹.** Expected UK Government support for CCS does not emerge (CCS Levy, carbon price floors, Green Investment Bank, Emissions Performance Standards finance). Also uncertainty regarding the exact modalities, timing and disbursement of funding.
- **Uncertain regulatory framework.** The required EU and UK regulatory framework for CCS doesn't emerge (nature of the EU CCS Directive's transposition into UK law; lack of storage permitting process/competent authority, uncertainty over storage pore space 'rental' costs etc.).
- **Insufficient EOR incentives.** The UK policy framework and support governing offshore oil and gas production in the North Sea does not sufficiently incentivise tertiary production using CO₂-EOR.
- **Long-term liability arrangements.** The liability regime for offshore storage of CO₂ remains largely unresolved and represents a key risk for storage site operators and investors.
- **Alternative abatement options.** Emerging EU and/or UK policy or Tees Valley emitters may directly or indirectly favour investment in abatement technologies other than CCS (once the project has begun construction or operation). There is therefore an opportunity cost associated with investing large amounts of capital in one technology i.e. CCS.
- **Planning process.** Planning requirements and barriers may derail the project (insufficient consents and permits to construct the key components of the network).

⁸¹ Just prior to this report being published, DECC announced consultation on fundamental reforms to the electricity market to ensure the UK can meet its climate goals and have a secure, affordable supply of electricity – see <http://www.decc.gov.uk/en/content/cms/consultations/emr/emr.aspx>

In addition, it may be possible that CCS technology does not gain sufficient public acceptance at the time of project construction and/or operation. This may be due to various issues relating to the perception of CCS (e.g. continued reliance of fossil fuel use, non-permanence of storage) or unsuccessful storage of CO₂ in the UK or elsewhere (i.e. evidence of leakage). Although not strictly a regulatory risk, it may impact upon the planning process and pose a reputational risk to those companies seeking to actively promote and/or invest in CCS plant or infrastructure on Teesside.

Regulatory and policy risks are diverse and include:

- Global, European and UK climate and energy policies – of which the potentially the most substantial concern the future of the EU ETS.
- Short, medium and long-term CCS-specific incentives and regulations (for example liabilities for storage operators)
- Support for enhanced oil recovery
- Relative policy support afforded to other CO₂ emission abatement measures.
- Planning and consenting

In addition, lack of public/NGO support for CCS may create a reputational risk to organisations developing CCS projects.

4.4 Technical and operating risks

This section considers risks relating to the performance of the technology and equipment across the value chain, the integration of the network components, and ensuring non-disruption to plant performance and managing the balance between CO₂ volume supply and demand⁸²

The development of CCS requires the integration of different engineering and technologies across the value chain (e.g. capture plant, power generation, pipeline operation, offshore storage site injection). Furthermore, a network capturing CO₂ from multiple sources and plant types necessarily involves a larger range of capture technologies and engineering challenges than a point-to-point solution. As opposed to most other carbon abatement technologies, the technology and operating risks associated with CCS are further compounded by the sheer scale of infrastructure and investment required. The commercial risks associated with deploying unproven technology - whose successful operation is intrinsically linked to the performance of other technology and engineering components - presents perhaps the greatest overall risk to potential network and capture plant investors.

Discussions with financiers confirmed the view that technology risk is largely an unacceptable risk for commercial lenders, and ‘first of a kind’ technologies rarely attract significant levels of debt finance. Insurance for the overall project is unlikely to be available given the lack of suitable reference projects⁸³.

Key operational risks associated with operating the network include:

⁸² It is common to manage such interdependencies in the energy sector through the use of Collateral Warranties (Calum Hughes, Yellow Wood Energy, Personal Communication).

⁸³ Some insurance will be available to cover failure of specific components.

- **Disruption to plant operation.** Challenges associated with capturing, transporting and storing CO₂ across the chain whilst ensuring uninterrupted commercial operations to emitters (for both the anchor project(s) and subsequent network users); the level of risk is likely to be greatest during construction and start-up phases (for capture plant, pipeline and storage site), but will also continue throughout the main operational phase of the CCS network. This will affect the output of the underlying activity, and therefore core business revenues.
- **Non-supply risk (“volume risk”).** A key issue facing the network developer/operator (and lenders to the oversized pipeline), arises from the potential under-utilisation of designed pipeline capacity. The unforeseen shutdown of connecting plants, new expected plants not materialising, and various technical and engineering failures across the CCS chain could result in non-supply of anticipated CO₂ volumes. This represents another material ‘first mover’ risk posing a critical challenge to developing a robust business case for investing in, and operating, an oversized network. Where revenues from EOR are required to help recover capital costs, the potential commercial impacts of non-supply are compounded further.
- **Non-demand risk.** The accompanying challenge to non-supply risk is where various factors along the value chain downstream of the capture plant(s) result in reduced or even no demand - relative to the volumes of CO₂ required operationally and commercially. Non-demand may arise from storage site injection problems or failure of EOR demand (for various technical and/or economic reasons).
- **Phasing and sequencing.** A host of technical and engineering challenges may result in the delayed or sub-optimal phasing of the network’s evolution and the successful sequencing of each required component of a commercially operational network. This could include technical constraints on common carriage of blended CO₂ streams from multiple sources, resulting in the strict imposition of CO₂ entry specifications which could subsequently prohibit certain connectors on a cost and/or technical basis⁸⁴.

Again, the interconnected nature of technology and operational risks is clear in the context of creating a value chain involving multiple parties. Understanding and managing non-supply and non-demand risk represents perhaps the core counterparty challenge to designing and structuring the project in a way acceptable to all parties.

Technical risks include disruption to operation, risk of non-supply of CO₂ from sources, risk of non-acceptance of CO₂ by storage sites, sub-optimal phasing of the network’s evolution, and constraints on the ability to blend CO₂ streams from multiple sources. These factors could impact costs, volumes and revenues of any CCS network.

⁸⁴ Any integrated pipeline network would require a common CO₂ entry specification (i.e. agreements on the maximum composition of impurities, and values for temperatures and pressures) so as to meet safety requirements. This may well influence decisions on capture and storage (e.g. suitability for CO₂-enhanced oil recovery). Decisions on entry specifications will usually follow cost-benefit studies of different specifications. One challenge with CCS is that our understanding of the techno-economics of capture and storage is rapidly evolving, so that the most economic system-wide specifications in 2030 may be different from those envisaged today. A second challenge is that the most economic specification for an individual participant (e.g. the specification preferred by a single source or storage site) may differ from the most economic specification for the system as a whole. The risk is that there may be a potential to lock-in an unfavourable offshore pipeline technical specification that forces some sources to develop their own network solution or simply not install CCS. This issue is however seen as a low priority by most stakeholders because the physical, chemical and hydraulic properties of carbon dioxide dictate a narrow CO₂ specification for any pipeline.

4.5 Approaches to managing risk

As described at the start of this section, the three groups of risk described above all serve to impact the commercial risk profile of the project as a whole, as well as each of the separate components (and therefore the exposure of all project lenders across the CCS value chain); the complexity described therein paints a challenging picture for the prospect of getting a CCS network off the ground in Teesside.

However, the nature of at least some of the risks highlighted are not new, and legal approaches and methods established for other large infrastructure investments can be applied to overcome many of them (e.g. liquidated damages clauses, long-term off-take agreements, take-or-pay contracts, non-disturbance agreements, facilities sharing agreements, collateral warranties, and so on). Therefore, using these as a basis, de-risking the factors described previously using these types of instruments will be critical to get the project off the ground. They need to be resolved amongst participants – at least in principle – at an early stage of the project in order to allow passing of key investment decision points. There are clearly a large number of risks and challenges which need to be understood and managed before investment is possible and the potential project structuring/ownership options can be assessed (Section 6).

Therefore, at the current time, any project promoter that could take the project forward needs to demonstrate that steps have been taken to understand these risks, and that contracts or agreements in principle or elements thereof are in place to manage them - even those that may occur towards the end of the project life. It is only after these steps have been taken can serious discussion regarding private (and even public) financial support for the project can be sought. An overview of the potential contractual linkages for a CCS network is highlighted below (Figure 16).

Although, as mentioned previously, many such arrangements are common practice to infrastructure projects (e.g. oil and gas production and transportation projects), the nature of CCS risks and the need for public support during the demonstration phase do pose additional complexities. Whereas many risks can be managed through traditional contractual arrangements, some are entirely exogenous, policy-related matters that presently act as potential 'deal breakers' for the provision of any private lender. The role of the UK government and possibly the EU are therefore critical to managing those risks that are genuinely unacceptable to private sector investors.

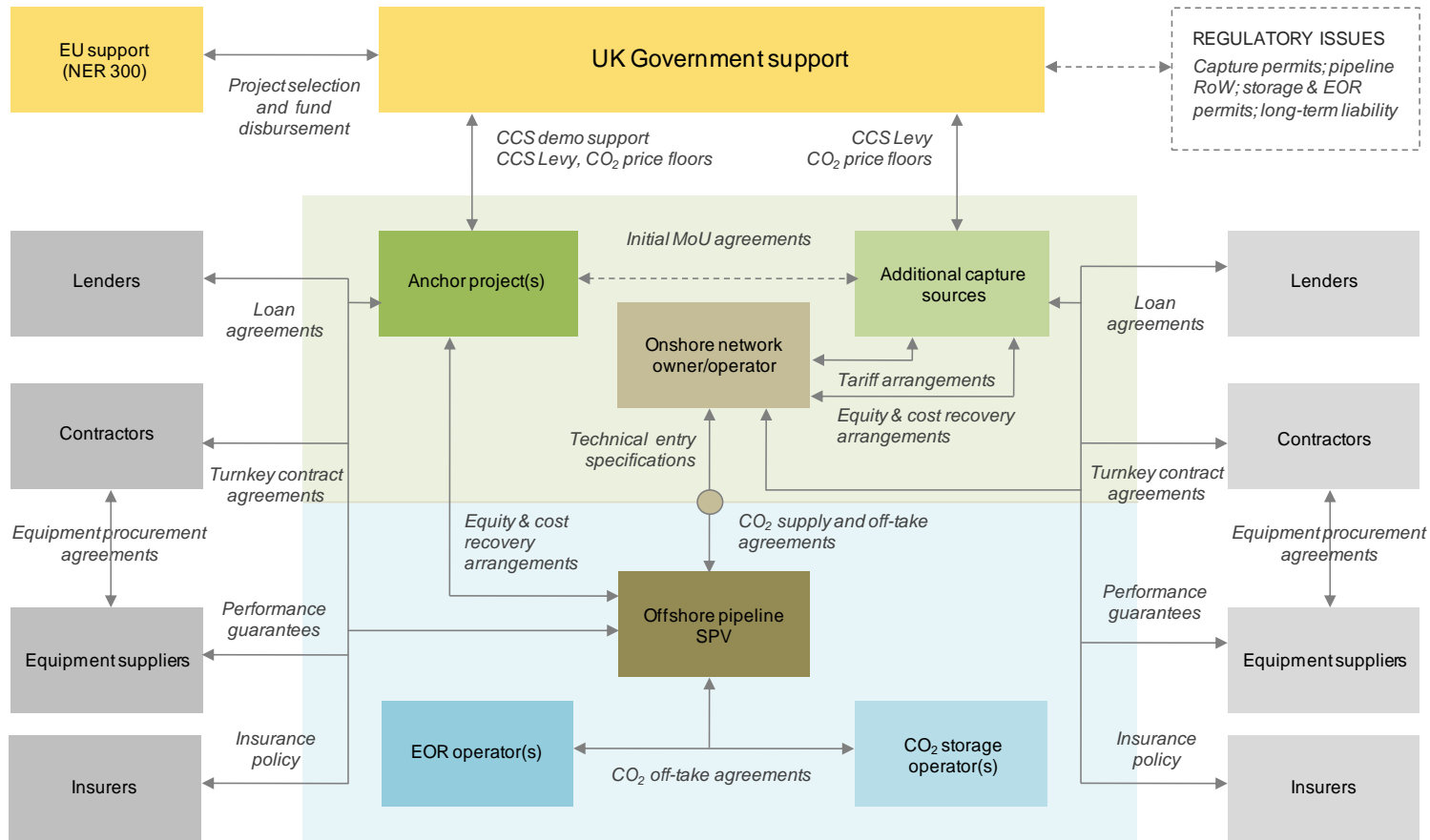


Figure 16 Contractual linkages for a potential CCS network

Figure 16 shows how a complex web of contractual arrangements needs to evolve in order to consolidate and manage project risks arising between counterparties. The figure is illustrative only, and much simplified. As well as employing specific contractual agreements entered into between counterparties, the appropriate design of project structure and ownership arrangements will also serve to manage overall project risk by appropriately distributing risks - and potential rewards - between parties. Project structure and the choice of contractual arrangements are therefore necessarily interlinked. For the purposes of illustration, just one simple model is shown - other options are possible and are discussed further in Section 6.

The various risks and challenges associated with building and operating a network on a commercial basis do not require an evaluation based on some form of risk 'ranking'; they are so intimately connected, with potential impacts across many parties, that any one failure in the chain could result in project failure. For example, network connectors cannot plan and invest in capture plant without the guarantee that sufficient network capacity will be available (and under what terms) - similarly, investing in an oversized pipeline can only be justified where there are guarantees of sufficient utilisation. There are similar mutual impacts associated with the construction phase(s) of the network. This 'project-on-project' risk creates additional risk exposure issues between counterparties, and requires additional legal and commercial arrangements to manage exposure and insulate counterparties to an acceptable level.

Therefore, the principal aspect to resolve for the network promoter will be the securing of necessary up-front commitments or guarantees around the future usage of a scaled-up network (e.g. long-term supply and off-take agreements). The need to address non-supply and non-demand risk is therefore at the core of the contractual framework for a CCS network. This issue is not uncommon in other projects based on investments requiring successful multi- or bi-lateral commercial relationships. The use of long-term CO₂ supply and off-take contracts between supply parties (i.e. by CO₂ capture entities and/or a mid-stream network operator), midstream operators (where these are separate to supply parties) and demand parties (i.e. CO₂ storage and/or EOR operator(s)) which are mutually agreeable is therefore a key priority. As with natural gas pipelines, the commercial arrangements are likely to be based on the need to secure known capacity levels (i.e. capacity rights, capacity payments, with ability to re-sell capacity rights in a secondary market). Such contracts generally also contain penalty provisions and clauses addressing specific concerns such as project failure or non-performance. Ultimately, it is this type of negotiated process, perhaps even involving bidding rounds or open-seasons for capacity rights, which will serve to determine the network capacity to be built at least in the first phase. Our discussions with Teesside stakeholders suggest that nearly three-quarters of those spoken with would potentially be interested in considering entering into an initial long-term supply contract for a Teesside network, either before 2020, or soon thereafter.

The need to address 'first of a kind' technology risk is also central to the success of the contractual framework and commercial basis of the network. Performance guarantees for equipment must be provided before lenders can consider investing. Again, because of the 'project-on-project' risk, these will be required across the entire system including each plant, all the capture equipment and any new build plants (known as a "wrap"). General performance guarantees do not typically provide for the full range of technical risks associated with operating the entire CCS network. For example, there will be concerns around whether emitting plants can operate satisfactorily with the capture equipment across all operating modes, fuel input variations and exhaust gas streams, over their

expected lifetime. As it is extremely unlikely that insurance for technology failure will be available, commercial lenders will therefore require equipment vendors to stake their reputation on providing performance guarantees for equipment. This will ensure that it is in the vendor’s interest to overcome any operational problems. To the best of our knowledge, few if any of these conditions are in place at present.

A further element to consider for shared infrastructure is the risk of change of ownership. This could affect incumbent contracts, and potentially prevent access to the system. Use of non-disturbance agreements will typically be required to manage this risk.

Table 6 summarises some of the key project risks associated with developing the CCS network and the range of potential approaches to managing them. The table shows that while many of the risk management options can be dealt with primarily by the private sector (through various commercial and legal arrangements typical of large multi-party investment projects), other areas of risk will likely require government policy and regulatory support. In this context, it is important to note that some CCS risks are viewed by investors as potential ‘deal-breakers’ unless addressed by the policy framework (e.g. EU Allowance price, long-term liability) whereas others can be managed through well understood existing approaches (CO₂ supply and demand risk, tariff arrangements).

Table 6 Summary of project risk and risk management options

	Key risk factor	Risk management approach	
		Commercial & legal (private sector)	Policy instruments (public sector)
POLICY & REGULATORY	Uncertain CCS policy framework	Contingency planning and insurance	Long-term policy commitments
	Uncertain CCS regulatory framework	Contingency planning and insurance	Robust regulatory regime for CCS
	Insufficient EOR incentives	-	Fiscal support for tertiary O&G production
	Long-term liability arrangements	-	Arrangements acceptable to CCS operators
	Planning process challenges	Coordinated approach to planning procedures	-
	Lack of public acceptance	Communicating benefits of CCS	Communicating benefits of CCS
TECHNICAL & OPERATIONAL	"First of a kind" technology risk	Equipment vendor performance guarantees EPC contractor insurance	Government guarantees
	Disruption of plant operation	Contingency planning and insurance	Compensation for loss of output
	Non-supply risk	Long-term supply contracts	Government guarantees
	Non-demand risk	Long-term supply contracts	Government off-take agreements
	Phasing and sequencing risks	Temporary tanker storage in initial stages Completion guarantees / arrangements	-
	Project-on-project risk	Commercial and legal insulation from counterparty risk and project failure (non- disturbance clauses, completion guarantees	-
	Loss of CO ₂ containment	Financial provision arrangements / liability transfer	Financial provision arrangements / liability transfer
ECONOMIC & MARKET	Project cost overruns	Completion guarantees	Government guarantees
	Low carbon price & price volatility	EUA price hedging instruments	Government carbon price guarantees (price floors, contract for differences etc) Increased stringency of EU ETS caps
	Economics of EOR	-	Fiscal support for tertiary O&G production
	Energy price increases	Energy price hedging instruments	-
	Sector-specific cost risks	Contingency planning and insurance	Compensation for loss of output
	Revenue risk (cost recovery)	Robust cost recovery and tariff arrangements	Government guarantees
	Barriers to market entry and exit	Network capacity rights with secondary market	Third party access arrangements

Government, if it wishes to leverage private finance into CCS projects, clearly needs to provide the required framework for addressing those risks that are genuinely

unmanageable and therefore unacceptable to the private sector. In doing so it is essential that public sector actions taken to reduce project risks to acceptable levels are balanced with potential rewards - whether these are project returns for shareholders and private investors or value to taxpayers. The optimal balance between public and private sector roles is a key factor determining the structure and ownership model of the project and is explored further in the next section of this report (Section 6).

Despite the organisational challenges involved in developing the 'contractual web' required to de-risk the network to a point where sensible investment decision-making can occur, it is important to note that the creation of multi-disciplinary teams and the coordination of multiple parties with appropriate contractual arrangements between them is not new to large-scale infrastructure, and in particular to Teesside. For example, the Tees Valley has a long history of shared infrastructure and common carriage of various commodities through pipelines, and such activities currently take place in the area (e.g. for ethylene, hydrogen or steam). The 'complexity of the web' is therefore not the main challenge to getting the project off the ground; where there is a commercial business case and sufficient financial backing, large infrastructure projects can progress through the necessary contractual stages, based on e.g. initial memoranda of understanding and letters of intent ahead of more detailed and binding legal agreements (including supply contracts). Instead, what is new is the demonstration of a commercial scale CCS network, and therefore whether the policy framework and economic fundamentals of the project are sufficient to attract finance.

5 Financing a Tees Valley CCS network

Financial investors, whether providing debt or equity, require a return on their investment over an acceptable period commensurate with their particular lending policies and reflective of the level of overall project risk they are exposed to. As seen in the previous section, although many of these risks can be managed through contractual and other arrangements, commercial risk is inherently linked to the fundamental economics of the project - significant capital outlay in early years, on-going operational costs, and the expected project revenues and/or avoided carbon costs.

It is also important to consider that given the nature of developing a CCS network involving the phased construction of both onshore and offshore components and multiple commercial entities across the value chain, different types of capital providers may be more or less suited to financing different elements of the network.

5.1 Sources of finance for a Tees Valley CCS network

As illustrated in Figure 17, different sources of finance are appropriate to different levels of technology maturity (i.e. risk and return profiles). The ‘anchor’ project, as a first mover, bears the highest risk (and therefore public finance, left hand side of Figure 17), but later sources connecting should be able to attract alternative classes of finance. Therefore, a CCS network will likely require a range of financial sources. Each commercial entity involved will have different approaches to and options for investment⁸⁵; the scale of investment required suggests a need for several capital providers to distribute risk.

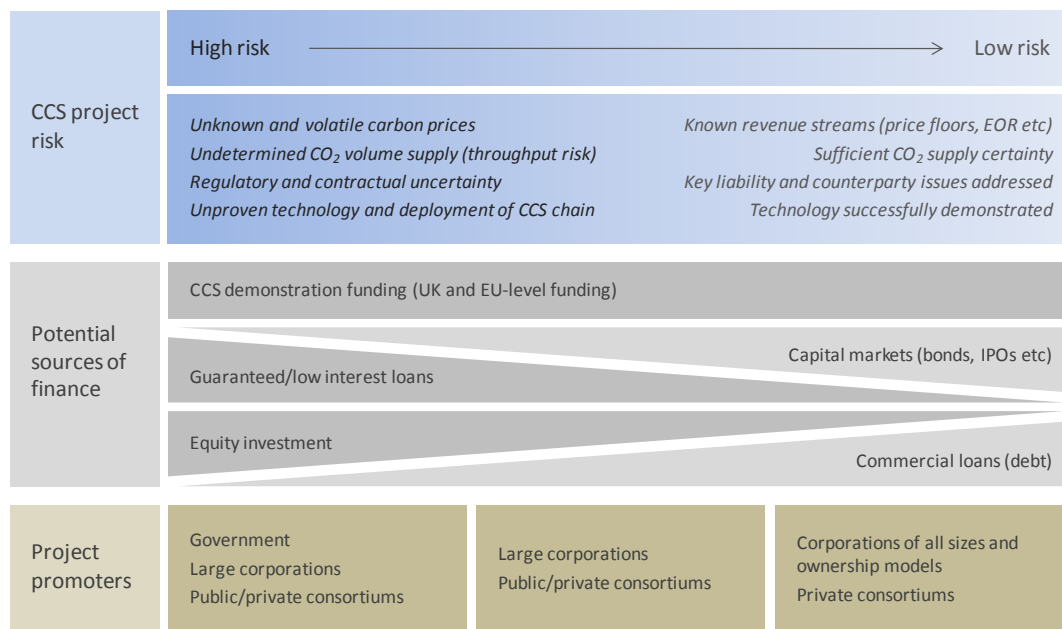


Figure 17 Potential sources of finance for CCS projects

⁸⁵Including for example, different levels of credit-worthiness

Eventually, when project risks can be suitably understood and managed, and where the carbon market and regulatory frameworks provide the necessary economic drivers/support for investment, the private sector should be able to mobilise the necessary resources to finance and promote the project (right hand side of Figure 17). However, whilst CCS remains unproven at scale and the required support framework is still emerging, project promoters are likely to require some form of public sector involvement.

When appraising project finance decisions, all capital providers undertake rigorous quantitative analysis to understand the commercial implications of 'worst case scenarios' for the cash flow model. For a CCS network, there are many factors potentially contributing to a worst case scenario (project failure, stranded assets and significant, potentially unlimited, liabilities). Even where key 'deal breakers' can be resolved and counterparty risks insulated, expectations of the potential for project failure, commercially as well as technically, are reflected in capital lending terms i.e. project returns over time. Equity is the only option for private finance where projects are deemed too high risk to attract debt finance; beyond certain levels of commercial risk, only public sector investment can be considered viable.

The sources of finance for a Tees Valley CCS network considered here are :

- **Grant** These include the EU NER 300 and UK CCS demonstration funding. Significant levels of grant will be required to help offset the large capital requirements for building a CCS network. Furthermore, several potential developments within UK policy may offer further support for CCS, although their details remain largely unresolved at present.⁸⁶ These could include the introduction of a CCS Levy on electricity consumers, the use of ETS carbon floor prices to insulate operators from future EU Allowance price uncertainty, and various mechanisms operating under a newly established UK Green Investment Bank (e.g. grants, soft loans, venture capital finance, project guarantees). The Global CCS Institute (GCCSI) – an Australian-led initiative designed to accelerate the commercial deployment of CCS projects - also has smaller funds available to support project development via its *Project Funding and Support Programme*. The fund has about AU\$50 M (approx £30 M) annually available for project implementation. The fund recently awarded the Rotterdam Climate Initiative (RCI) AU\$2.2 M (approx. £1.2 M) for an independent assessment of storage sites, a feasibility study in to transport options – including shipping – and a project 'benefits' assessment. In the future, other national, European, or global transport infrastructure public funds may become available for CCS infrastructure.
- **Equity**. Major emitting plants and potentially other interested corporate parties (chemical companies, manufacturers, utilities, midstream specialists, storage operators etc.) could take an equity stake in a pipeline infrastructure SPV company (or separate onshore and/or offshore SPV companies). Equity requires higher project returns to shareholders than debt finance, but guarantees a firm commitment to project success by the parties involved. In order to retain good credit-worthiness, any investment in CCS would likely need to represent a small share of the parent company's overall asset base to limit exposure (for example, limited to around 2% of the corporate asset base etc.). Capital investment would almost certainly be needed to build each network user's capture plant, and in some cases may be within the scope of typical on-balance capital budgets (as suggested by discussions with Teesside stakeholders - see Appendix 1).

⁸⁶ The degree to which these are paid out up-front or based on performance (e.g. through a contract-for-difference with the carbon price) has not yet been determined.

- **Debt finance.** Commercial lending for project finance typically complements equity. The commercial terms upon which project finance is provided are based upon an acceptable commercial risk profile, with a cash flow model generating revenue streams to recover capital outlay across an acceptable period. Where capital is provided for plant and equipment, commercial lenders require solid performance guarantees, and major project sponsors providing project equity, typically commensurate with the level of risk associated with the project. A syndicated loan may be provided by a number of lenders, with one commercial arranger. This allows lenders to manage the exposure of their investment portfolio, particularly given the large capital requirements for CCS infrastructure and competing sources for capital, compounded by the recent financial crisis.
- **Infrastructure investors.** Infrastructure investors typically specialise in providing significant amounts of capital in early stages of large project developments with well-understood cost and revenue models (transport, energy, utilities, and communications). Discussions with infrastructure fund providers confirmed the view that such institutions are extremely averse to technology risk and unlikely to accept the “first-of-a-kind” construction, project-on-project and operational risks associated with a CCS network investment. They can effectively place debt into lower risk projects with proven technology, known revenue streams and well understood project challenges. The present opportunity cost of investing in CCS is high, with many lower risk investment opportunities currently in the market for these types of players as a consequence of various economic stimulus packages introduced by Governments over the last two years. That said, there is some residual interest amongst infrastructure fund specialists in potentially being involved in early CCS projects in a small way (e.g. 5% debt financing of investment needs), albeit with recourse to well-capitalised equity investors in order to insulate their risks.
- **Private equity and venture capital.** Specialised equity such as venture capital (VC) is commonly applied to emerging technologies and relatively speculative project investments. Private equity funds typically operate a business model based on a large portion of debt funding, which is unlikely in the case of a demonstrating a CCS network. Also, the size of the funding required to deploy CCS at scale on Teesside is probably in excess of typical private equity involvement, whilst typically they invest in proven industries with established business models where certain short-term modifications to operations can lead to profitable exits typically within 3-5 year time frames; criteria certainly not applicable to CCS at the current time. Venture capital finance is more suited to higher risk technology projects such as CCS and has been successful in developing a range of new and emerging technologies to date, including renewable energy. However, the economics of the CCS network suggest that the returns typically required from venture capital (25-35%) are highly unlikely in the short-to medium term. Moreover, there are few if any VC funds willing to accept the level of risk and equity investment required for CCS at this time. As demonstrated earlier in this report, the cost of network service required to meet such high levels of desired returns would likely be prohibitive to most potential network users - and connection from these emitters would be required to build and operate the network at an acceptable capacity in the first instance. On this basis, it is difficult to envisage a role for VC in the Teesside network at this time.
- **Multilateral public funds.** Multilateral public funds provide finance for projects which meet policy objectives but may face significant challenges to attracting conventional investment such as commercial debt finance. Loans, guarantees and other financial support instruments are typically provided on favourable terms compared to those

required by the private sector for similar levels of project risk. They have therefore been used to develop infrastructure and other projects where there is significant commercial risk, and have also helped to commercialise other areas of new energy and low-carbon technologies. Potential funds applicable to CCS demonstration include the Risk-Sharing Finance Facility (RSFF) operated by the European Investment Bank (EIB) and potentially the UK Green Investment Bank (GIB). Multilateral finance can also play an important role in helping to attract other financing partners.

5.2 Relevance of different options for financing a CCS network in the Tees Valley

Table 7 summarises the potential sources of finance based on each source's view of commercial risk associated with CCS, their typical project return requirements, and their potential involvement in a network investment. Based on these factors, their overall suitability as a source of project finance for a CCS network is also summarised. The contents of Table 7 draw heavily upon discussions held with legal and financial service providers, the survey of Teesside industrial stakeholders (See Appendix I), and the recent report undertaken by Ecofin and the Climate Group on Mobilising Private Sector Finance for CCS⁸⁷.

⁸⁷ The Climate Group/Ecofin. Carbon Capture and Storage: Mobilising Private Sector Finance (2010). Available at www.globalccsinstitute.com

Table 7 Potential sources of commercial finance for a CCS network

	Public finance		Private finance			
	Grants	Multilateral funds	Project finance debt	Infrastructure fund investors	Corporate finance (equity)	Private equity and VC funds
View of key commercial risks	Made available due to high capital costs and project risk for CCS. Successful NER300 proposals must meet certain criteria (incl. demonstrating realistic prospect of project operation within required timeframe; permits and national legal framework being in place)	Multilateral investors such as the EIB employ a range of funding instruments to support policy-driven project finance deemed high-risk by commercial lenders. Loans are subject to an assessment of viability and bankability.	'First of a kind' technology risk, 'project on project risk' and absence of robust long-term revenue streams would likely restrict most lenders in absence of significant government financial support / guarantees	Low appetite for providing project finance to unproven technology with significant commercial risk	Opportunity risks associated with investing in CCS compared to other capital projects. Numerous project-on-project risks (including sequencing and supply/take risks)	Unlikely to attract private equity due to large scale and multiple risks. Venture capital well suited to new technologies with corresponding commercial risk profile
Typical project return requirements	Not applicable. However, future grant schemes may include provision for public sector returns in event of project return achieving certain levels.	Loans provided by multilateral banks such as the EIB are typically based on low and favorable terms i.e. overall returns, repayment periods and conditions. Debt may also be subordinated to other (senior) debt providers.	Investment considered only with technology risks addressed and large share of equity from major sponsor(s); likely to require IRR of 15-20%.	In view of project risks, likely to require IRR of 15-20%	Varies according to size of investment and company. Where risks can be addressed, may range from around 10% to in excess of 20% IRR. Potential size of investment per corporate likely to be limited to £10m's for most	IRR in excess of 30% required, given technology risk and large size of investment
Potential involvement with Network	NER300 applicable to the anchor project(s) only. Up to 50% of the CCS costs can be funded through the NER300. To be awarded NER300 funding, the project must demonstrate the full CCS chain (capture, transport and storage). The funding can therefore be used to support investment across the full anchor project chain.	Support via funds such as the EIB RSFF could potentially be used to match other finance sources (commercial debt, equity, UK support) used to build the over-sized offshore pipeline, and potentially the on-shore network. EIB loans are capped at 50% of total project capital requirements.	Potential for non-recourse or limited recourse finance with possible mezzanine and syndicated arrangements. However, large risks of project failure and stranded asset risk. Potential for involvement in onshore and/or offshore pipeline infrastructure based on revenue model (tariff; off-take agreements etc.). Some banks may have interest in CO ₂ off-take arrangements.	Commercial business model most suited to investing in pipeline infrastructure with returns based on tariffs from connectors and/or EOR operators	Offshore pipeline infrastructure likely to attract equity from large companies and project sponsors only. Smaller companies and secondary connectors may invest in capture plant and onshore network through a joint venture (e.g. special purpose vehicle, SPV).	Likely limited to specific elements of capture equipment demonstration
Suitability to financing Network	Grant support to anchor project(s) finance needs is an absolute requirement for CCS network development within foreseeable future.	Suited to providing up-front capital requirements for network development, and potentially on-going lending support.	May provide limited amounts of debt where project sponsors can provide bulk of capital requirement through equity. Potential involvement as part of refinancing after Network and storage is proven	Potentially small-scale involvement via provision of a small amount of senior debt. Potential involvement as part of refinancing after Network and storage is proven	Absolute requirement in absence of government entirely financing CCS Network. Emitters have most to gain from successful project deployment and strong track record of investing in joint infrastructure on Teesside	Unsuitable

5.3 Conclusions on financing options

In terms of potential finance sources, the following key conclusions can be drawn:

1. **Up-front grant support to the anchor project is required for the network development.** Because of the considerable capital requirements, the technology risk involved, and, at present, the insufficient carbon price signal upon which to base a long-term stable cash-flow model, up-front EU- and/or UK-level support will be essential to help offset investment requirements and attract additional private finance and participation from potential network connectors.
2. **Commercial debt is unlikely to be available to get the project off the ground.** 'First of a kind' projects without business models built on steady and predictable cash flows are unlikely to attract significant commercial debt finance. Even under favourable economic conditions, it is likely that only 5-10% of the required up-front capital costs for building a network might be available as commercial debt finance, and only then with recourse to well capitalised equity players.
3. **Refinancing is possible once a successful network is demonstrated.** The network could be refinanced at a later date (in which project equity is converted into debt), when key project milestones have been overcome, the value chain and storage site is proven and the project is suitably de-risked. Refinancing would reduce the cost of project capital, thereby improving the overall economics of the project and potentially allowing for a reduced cost of network use. The UK government has undertaken this kind of action through the privatisation of a number of key public assets over the years.
4. **Equity investment will be essential.** Financing and building a network on Teesside will need a 'coalition of the willing' able to provide significant equity into the project development. Equity takers would likely allow large companies with a strategic interest in CCS to finance their share of a network project from their balance sheets (or via corporate finance or share issues), subject to scale and the business case fundamentals (or technically off-balance sheet, through the use of special purpose vehicles; SPVs). Equity from established and committed participants will be critical to unlocking additional sources of finance, including the various options for refinancing once the network is proven. The level of money sponsors are prepared to invest will provide a measure of how serious they are about the success of the project. However, the scale of investment, coupled with the counter-party risks to equity holders poses an enormous challenge to most companies, particularly given the on-going pressure on capital budgets in the current economic climate.
5. **Project sponsors must have good track records.** Project sponsors/equity takers will need to be large companies with strong proven track records in managing and delivering large complex projects. The commercial credit rating of potential network users is also a key issue, determining their ability to participate in the CCS network (in terms of their ability to invest in on-site capture plant as well as providing equity in the onshore - and potentially offshore - network). Discussions with financiers confirmed that commercial lenders prefer financing projects where project sponsors 'have deep pockets' - there is good experience on Teesside from several large well-capitalised companies developing and investing in joint infrastructure projects.
6. **Private equity and venture capital.** Considering the level of technology risk associated with CCS, specialist finance such as private equity and venture capital would require project returns unacceptable to the project economics (and network users). The scale and timeframe of the investment required is also unsuited to private equity and venture capital.

7. **Government support will be critical to attracting private capital⁸⁸.** Given the concerns of private lenders in relation to the commercial risk profile of a CCS network projects, it is likely that some of the project challenges can only be accepted and/or addressed by the public sector. In addition to the demonstration funding required to offset some of the incremental capital costs of CCS, Government can potentially provide support through the creation of stable revenues streams (carbon floor prices⁸⁹, revenue guarantees, decarbonised obligations, energy performance standards), providing additional support throughout the project cycle (Regional Growth Fund⁹⁰, CCS Levy, performance-based funding) and providing soft loans, structured finance and project underwriting/guarantees to cover technology risk (e.g. via the Green Investment Bank). There may be an option to use the free allowances for industry and cash compensation for indirect emissions to finance the development of CCS. Public support will be required to de-risk those aspects that are unmanageable and therefore deemed too risky by commercial lenders; use of public funds to support projects will provide the confidence in the emergence of effective policies and regulations upon which the commercial success of the project is contingent, potentially providing a route to leverage private capital into CCS demonstration. Once the concerns of lenders are reduced, the role of government can be lessened.

Finally, the revenue streams provided by enhanced oil recovery (EOR) could significantly change the economics of the CCS network and therefore the availability of private investment. EOR can provide a revenue stream that could enhance overall project economics. Once a significant and predictable volume of CO₂ is captured from Teesside and the offshore storage is proven, the potential for diverting CO₂ for tertiary oil production using EOR may serve to attract additional sources of private finance. However, given the limited window of opportunity and high complexity for EOR, unless EOR activities can be guaranteed up front, it should only be viewed as the ‘icing on the cake’ providing additional potential upside for network sponsors.

There is considerable activity to develop financing mechanisms to support large scale low carbon infrastructure beyond the above established mechanisms, so that it will be necessary to review the conclusions contained within this chapter on an on-going basis.

Financing for higher risk projects typically comes from public grants, equity investment, and guarantees. Capital providers will dictate required returns on the basis of quantitative examination of scenarios. Up-front public grant support to an anchor project is required. Debt finance (e.g. through syndicated loans) is likely to be limited, although over time once risks have been reduced there would be a number of options for refinancing with lower cost of capital. Strategic equity investment will be required from a coalition of willing sponsors – who will need good track records. Government can leverage private finance through removing risks. Unless EOR commitments are made up-front, they should only be viewed as providing upside potential.

⁸⁸ Just prior to this report being published, the Government issued a Call for evidence on long term development of CCS infrastructure, available at http://www.decc.gov.uk/en/content/cms/consultations/ccs_3rd_party/ccs_3rd_party.aspx

⁸⁹ Interestingly the wide range of prices for individual businesses highlights the challenge to Government in setting a single carbon floor price, i.e. any given price more than required for some emitters (dead weight losses) and insufficient for others.

⁹⁰ <http://www.bis.gov.uk/policies/regional-economic-development/regional-growth-fund>

6 Project structuring and ownership

The previous two chapters highlighted the nature of commercial risks, how these can be managed and how these play out in terms of financing challenges for a CCS network in the Tees Valley. Finding the right balance between risk, reward (revenues) and the sources of finance will be critical to creating a commercially viable project proposition for the CCS network. This may be achieved through appropriate structuring of the project with respect to its promotion, ownership, financing, design, construction and operation.

This section sets out how the project could be structured in different ways to take account of the risks and sources of finance in order that an optimal solution may be delivered. An optimal solution is one where all parties are effectively insulated against the risk of failure of one another, and where the risks (and rewards) are effectively distributed to those parties most able to accept them (or for rewards: are merited on the basis of risk appetite). However, it should also be noted that in reality, the most optimal solution may not be possible due to prevailing policies of key stakeholders at the current time.

Options for project structuring

Figure 16 highlighted the number of actors and agreements that need to be in place, and by inference the complexity involved and coordination needed to get a CCS network off the ground. Finding an appropriate structure for the project will help to manage, consolidate and reduce counter-party risk between the different actors involved, and therefore significantly influence the ability of the project to attract private finance, and the cost of that funding.

Appropriate structures can consolidate and simplify relationships between parties, reduce the number of entities involved and the number of counter-party agreements needed, and allow for common commercial linkages between entities to evolve. To illustrate this, we can envisage two scenarios which cover options at each extreme of a spectrum available for project structuring:

1. **The laissez-faire model.** At one end of the spectrum, the laissez-faire approach requires each entity to operate independently with an absence of centralised coordination (i.e. no promoter). The web of agreements and contracts would need to evolve organically, financing for each component would need to be obtained independently, and the design, construction and operation of pipeline network would need to evolve with limited foresight, with each operator taking on responsibility for their own segment to the point where another operator takes on the responsibility. This is a very challenging prospect indeed.
2. **The centrally planned model.** At the opposite extreme of the spectrum, a centrally planned approach would involve a single entity stepping in and taking responsibility for to promote, design, build, finance, and operate the onshore network, the offshore pipeline, and the storage/EOR (a design-build-finance-operate - DBFO - model). An extreme variant could also see the same entity taking on responsibility for investing in and operating capture plant at connecting installations.

The laissez-faire approach probably corresponds more closely to the current situation in the Tees Valley. It relies on the organic development of the system amongst interested

parties, and is unlikely to succeed. In this model, the ownership and development of the underlying CO₂-generating business, capture, compression, onshore transport, shoreline compression, offshore pipeline, storage and any potential EOR facilities may be quite fragmented. The approach is not able to mitigate regulatory and policy risks, technical or particularly operating risks (the risk of counter-party default would be high), whilst each entity would be exposed to the specific market and economic risks faced by each individual company involved in the chain, with limited recourse. As such, the approach faces a very high risk of failure as the breakdown of any one counter-party link would leave the project stranded. Furthermore, there would be no obvious mechanism to coordinate the different actors, apply for finance, design the system, making it impossible to effectively raise finance for the project. The approach is unstable, impractical and unworkable. The network clearly needs more active coordination.

A centrally-planned system would require either (a) the UK Government to promote, finance, design, construct and operate the project or (b) the introduction of an agency or a regulated utility acting with a direct mandate to act on behalf of Government – or a mandated entity – would potentially have the power to impose regulations that force operators to mandate the installation and operation of capture plant; ensure appropriate planning consents achieved etc. serving to de-risk the project significantly, leaving just technology failure as the single source of project risk. If Government were to take on this role, it would be required to make a very large investment of time and resources to make it happen, which is not in alignment with current UK government policy for infrastructure development, and certainly does not fit with the current constraints on public-sector capital⁸⁸. Note however that this approach has been taken in Norway³⁷, which has created the Gassnova company to fully own and manage capture, transport and storage.⁹¹

Potentially, Government could introduce similar laws whilst simultaneously introducing a Government sponsored Agency or private entities into the process, effectively setting up a public-private partnership (PPP). This would in essence create an agency or regulated entity – similar to the Nuclear Decommissioning Agency or National Transmission System (NTS)/National Grid Limited (NGL) – with responsibility for taking a DBFO approach to the network. Government would stand behind the entity in terms of creating supporting regulation and acting as lender of last resort (guarantor in the event of technology failure). Governments views on this approach are somewhat mixed (see Box 1) with a clear approach yet to emerge. Therefore, at the current time there is no mechanism by which government could introduce such an approach. One idea on the table is the introduction of a National Carbon Storage Agency (NCSA)⁹², which Ministers seem to be taking seriously (Box 1). The proposed Government “CCS Roadmap” – planned for 2011 – is intended to go some way to further clarifying the options (Box 1). Further complicating the matters is Government proposals for a Green Investment Bank (GIB), which could stand behind some of these risks at arm’s length from Government.

⁹¹ Effectively a ‘waste disposal business’ model.

⁹² Lord Oxburgh, J. Gibbins, G. Sweeney and A. White (2010) Working Party Report on the arrangements needed to develop Carbon Capture and Storage in the UK. UCL Faculty of Laws. Based on a paper to the Energy Group of the Conservative Party.

Present policy messages from Government leave flexibility on the approach to delivering pipeline infrastructure for CO₂.

In recent speeches made to the 1st CCS Senior Stakeholder Conference in July 2010, both Chris Huhne and Charles Hendry – Secretary of State and Minister for Energy respectively – talked of the need for Government to “work in partnership with business” to get CCS going. Charles Hendry stated that “innovative financial services” will be required to devise solutions to mobilising the “vast amount of capital needed”. He also added that the UK demonstration programme already includes support for the nascent infrastructure that will be necessary to support the deployment of CCS throughout the economy, noting that if the UK is to make a real success of carbon capture and storage, it has to develop the infrastructure of pipelines and encourage clusters of those facilities in certain areas. He further acknowledged that a number of regional bodies are considering how the development of regional CCS infrastructure will help them sustain and attract high carbon emitting industries in a carbon constrained world, and how they can stimulate the development of that infrastructure through regional partnerships His footnote to this was that Government has to take a long-term strategic view, and therefore will also look at the sort of infrastructure that will be needed to deploy CCS beyond the demonstration stage and how the UK can use the demonstration programme to set the seeds for that future. He also added that further consideration of what more Government could do to help this process, including a role for an Agency as recommended by Lord Oxburgh [to the Conservative Party Energy Committee] (op cit).

This is a more progressive view for future proofing the UK CCS demonstration projects and related pipeline infrastructure than expressed four months previously (under the previous administration). In the report “Clean coal: and industrial strategy for the development of carbon capture and storage across the UK” (March, 2010), the Government of the time concluded that the establishment of a central agency “would be premature at this time”, and that the demonstration projects “would require no more than four pipelines...[and]...consequently, the opportunities for network integration and ‘masterplanning’ are unlikely to be significant during the demonstration phase”.

Very recently, the Government has issued a Call for Evidence on Developing Carbon Capture and Storage Infrastructure. In this the Government has explicitly (i) recognised the economies of scale inherent in pipeline transport; (ii) confirmed that projects securing demonstrating funding will be able to invest in additional pipeline or storage site capacity at marginal cost; (iii) identified that the risk of stranded assets are not materially different if the investment is privately or publicly financed; (iv) solicited opinions on the benefits of centralised and decentralised models of developing CCS infrastructure.

In a decentralised model for developing transport infrastructure, decisions on design (e.g. routing and capacity) are left to the market, although optimised through creating formal open season arrangements so other parties can make their interest known in joint developments, providing an obligation to provide taps and interconnections to facilitate growth of the network, unbundling transport ownership, developing a secondary market in pipeline capacity to ensure efficient utilisation, and a regulated tariff structure to control the basis of charging for pipeline access.

In the central approach, benefits identified include strategic planning, impetus to develop private-public funding partnerships, and managing contracts between emitters and stores. Challenges include acquisition of infrastructure funded under the demonstration programme, reducing the opportunities for commercial development of transport and storage businesses, loss of incentive to maximise efficiency, inconsistency with the approach to funding investment elsewhere in the economy, and increased pressure on the public finances. A central authority could be charged with oversight of aspects of transport

Box 1 Recent UK Government views on CCS infrastructure financing⁸⁸

Neither the laissez-faire or centrally-planned approach appears practical or feasible in the near-term. The organically developed system is not stable enough to emerge, whilst the possibility of a centrally planned system emerging seems some way off from

Government's thinking. This leaves various options lying between these two extremes. In this context, two modes for project development and structuring are possible:

1. **Single entity promoter.** This would require the emergence of a single, risk-seeking, well-capitalised and/or creditworthy CO₂ capture plant owner or midstream promoter stepping in to develop the project. However, such 'midstream' promoted projects are generally the most difficult projects to realise as the promoter has little or no recourse to the underlying asset creating entities. It would rely on the development of watertight supply and off-take agreements, or a very robust demand-case for CO₂; the latter could only really come from EOR.
2. **Joint Venture (JV) development.** This would involve a coalition of willing Tees Valley (and potentially other) operators joining together to form an investment entity (special purpose vehicle company; SPV) under which they would develop the onshore network, and potentially the initially over-sized offshore pipeline. This would require these entities to put finance directly into the SPV as equity, and also possibly try to attract private capital into the project (debt), as described in the previous section.

6.1 Single 'midstream' promoter

A single promoter could involve a large company with appropriate expertise (e.g. E.On, BP, Shell, Linde, National Grid etc.) making the necessary investment, based on a speculative view of the business case for the future use of the pipeline⁹³. Whilst these companies are not risk-averse, they would face significant opportunity costs.

Smaller specialised promoters could also be interested. Progressive Energy has established a shell company – COOTS – as a potential investment vehicle. However, whilst small companies may be risk-seeking, and have a single business model predicated on CO₂ supply and demand, they would need to be suitably capitalised / creditworthy to attract the level of investment that would be needed to fund the Teesside onshore network and offshore pipeline. Moreover, as highlighted above, as such companies would not have any direct interests in the underlying value creating entities (i.e. CO₂ sources or EOR off-takes), they would face the greatest challenge to get the project off the ground. Therefore, in our view, the emergence of this option in isolation from operators in Teesside - seems unlikely at the current time.

6.2 Joint venture approach

The JV model holds more promise. Equity involvement by operators of the underlying assets that create value (i.e. the emission sources) would significantly de-risk the project from the point of view of non-supply risk, probably the most important factor affecting the commercial viability of the transport infrastructure. This could include the "anchor" projects that could gain UK CCS Demonstration finance, and potentially other Tees Valley operating companies that are well-capitalised and creditworthy entities (e.g. SembCorp, SABIC, GdF Suez). The involvement of these entities could significantly improve the chances of attracting private capital, either through share issues, corporate finance (debt) or, most likely, project finance (debt).

⁹³ This is how gas pipelines have been built in the past e.g. BP and partners built the CATS pipeline in view of the anticipated demand from many small gas fields in the Southern Central North Sea area, and recognising that individually none of the field developments could justify the investment into the pipeline, even though it made economic sense in combination.

Financiers would expect to see well-capitalised entities with significant equity interests involved in the project before they would even consider the scope for project finance for the CO₂ network on Teesside. The presence of the ‘anchors’ in the JV, and creditworthy equity investors, would lead to a stable project proposition.

The likelihood of the JV approach emerging is dependent on each entity’s individual EU ETS exposure, its cost of capture (particularly versus other potential abatement options), and its access to capital. We have not made a detailed assessment of these factors in this work. However, the results from a survey of Teesside operators indicated that most operators considered that CO₂ capture plant could be financed by the company’s capital investment programme (58%) suggesting that the JV would have support from operators in the area. Further, the majority of operators surveyed considered that a consortium approach – including a PPP or wholly privately-owned entity – would be the most effective means of developing a CCS network in the area.

There is a strong track-record for developing joint infrastructure in the Tees Valley, and many would likely consider this a similar exercise, so long as a robust business case exists.

Table 8 Assessment of CCS network project structure options

Structure option	Commercial risk profile			Likelihood of funding	Likelihood of success
	Policy & regulatory	Technical & operating	Economic & market		
Laissez-faire	Significant without government support and intervention	Significant, and compounded by multiple parties and interests ('project on project' risk unmanageable). Structure very unstable.	Significant, and compounded by multiple parties and interests ('project on project' risk unmanageable)	Extremely unlikely	Extremely unlikely
Centrally planned	Effectively addressed due to government acting as project sponsor as well as primary policy-maker / regulator	Technical risks remain but can be underwritten by government; key operating risks can also be managed through use of government supply and demand guarantees	Effectively addressed as government has capacity to create new regulation and economic framework to support objectives, and enforce payments in cash-flow model	Extremely high, due to government involvement and commitment (subject to incentives and project terms)	Contingent on the development of new government policy and regulation; approach at odds with current UK policy approach
Single entity led	Significant without government involvement, project guarantees and support.	'First of kind' technical risk remains overriding barrier to attracting commercial debt. Non-supply and demand risks can be addressed through design of suitable contractual arrangements.	Significant, exposed to all non-supply and demand risk due to limited involvement of underlying users of network ("midstream issues").	Challenging, and likely based on project sponsor's credit-worthiness and access to capital (corporate finance). Few corporate sponsors likely to have sufficient profile.	Unclear, and dependent on profile and track records of project sponsor in addition to level of government support
JV consortium	Significant without government involvement, project guarantees and support.	'First of kind' technical risk remains overriding barrier to attracting commercial debt. Non-supply and demand risks can be addressed through design of suitable contractual arrangements	Effectively addressed, as equity involvement ensures commitment of partners with interest in underlying assets i.e. direct link to network users.	Likely to be promising, subject to developing a strong corporate 'coalition of the willing' with good track records and credit ratings	Dependent on level of equity involvement and ability to de-risk counterparty commercial linkages. Proven track record on Teesside in building investment consortia and facilities-sharing.

On the basis of the discussion outlined, we consider the JV model using a project finance approach to be the most promising method for near-term promotion of a CCS network on Teesside. Some observations on how the SPV could function are discussed below.

6.3 A joint venture development in practice

A JV approach using an SPV and project finance model offers the greatest means to insulate risks across the CCS value chain that could emerge in the Tees Valley. It also offers the most effective means to potentially leverage private capital (debt) into the project though the presence of well-capitalised, creditworthy counterparties.

In practice, the options to structure the networks operation under this model include:

1. **Anchor project led only.**
2. **Anchor projects plus large emitter led.**
3. **Anchor projects plus large emitter led, plus smaller entrants.**

This concept is shown graphically below (Figure 18).

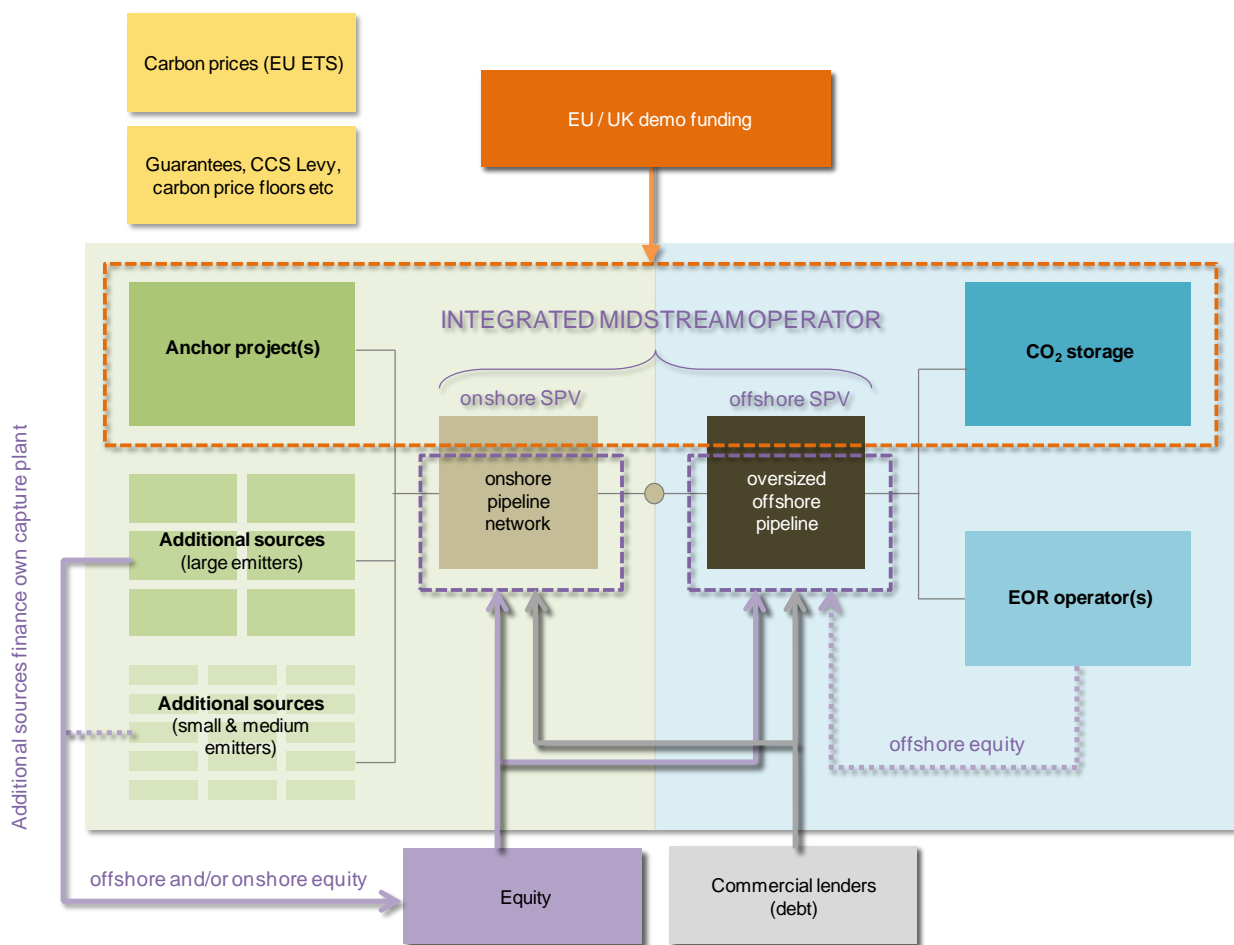


Figure 18 Potential ownership structure of the assets across the Tees Valley CCS network chain.

These are only initial high-level observations on how the network ownership and development could be structured in practice. Clearly, significant effort needs to take place to be in a position to establish these types of arrangements, recognising the risk and financing challenges described previously (Section 7).

Once established, the system could offer a reasonable amount of flexibility. Two of the scenarios would involve setting market entry requirements, which would offer scope for future exit and entry of direct participants and new market entrants. Furthermore, once built and proven, the equity holders could potentially exit and/or refinance, leveraging new sources of lower cost commercial debt (including mezzanine arrangements, structured finance), which could serve to lower financing costs.

In practice, a structured and negotiated process will need to emerge that serves to bring the JV partners along, requiring first the development of initial memoranda of understanding, collaboration agreements, moving then towards letters of intent and finally structured contracts and a SPV entity with its associated articles of incorporation and shareholder agreements.

6.4 Tariff setting and market regulation

Where market entrants are potentially involved, there would be a need to establish tariff setting procedures for entities connecting to the network. Four very basic models could be used:

- **Capacity model.** This would involve fully charging the entrants for their planned capacity, rather than throughput. It would insulate the pipeline operator from the non-delivery risk associated with technology failure or carbon and energy price economics. Full capital cost recovery could be achieved through this approach based the unitised capacity cost for whatever the period the capacity is contracted for. It is unlikely, however, to be an attractive proposition for market entrants as it exposes them to the full cost of transport even in the event that they don't connect.
- **Capacity plus throughput model.** This involves pricing the service based on a mix of capacity and service. The precise ratio of each will be directly proportional to the level of risk/insulation achieved by the network operator, as well as what the market could tolerate.
- **Throughput model.** Pricing for services would be based entirely on the level of use of the pipeline by capturing entities. This approach fully exposes the network operator to non-delivery risks, and would therefore likely involve adding a risk premium to the charge.
- **Take or pay agreements.** These would need to be in place between the network operator and either/or the offshore pipeline operator and/or the storage site operator.

Clearly, the precise entry requirements and service costs will need careful negotiation. However, Tees Valley operators are well-versed in these type of contracting procedures, and could likely rapidly modify variants of existing agreements in order to establish the precise nature of the contracts.

In this context, previous studies on integrated network solutions have suggested that the market may require a regulator to control monopolistic behaviour, and to avoid the risk of one being established post-construction that could modify any agreements set out at the start of the project. Previous studies suggested that this would build confidence of

investors in the project⁹⁴. Our discussions and survey of Teesside stakeholders, legal experts and financiers did not highlight this aspect as an issue. As highlighted previously, there is a long track-record on Teesside of private self-regulated cooperation on pipeline infrastructure, and well established contractual procedures in place to accommodate such arrangements.

In our view, Teesside operators are well-positioned to self-regulate the development of a CO₂ network in the Tees Valley absent of the need to establish an independent regulator. Government policy in this area is unclear, although it has been mooted that the Office of Gas and Electricity Markets (OFGEM) could serve such a purpose.

6.5 Onshore and offshore development

Whilst most of the previous discussion has refrained from considering technical split of the system, the onshore and offshore components of the transportation vary significantly in engineering requirements and costs. However, the value chain for CCS in Teesside could – with the emergence of EOR – build from both the source and sink, with different drivers for entities at each end of the value chain. Further, the onshore pipeline is more akin to a low-pressure *distribution* network, taking CO₂ from sources (suppliers), with scope for phased development of various pieces of the grid as new connections emerge, and costs in the region of £50 million – these are aspects well within the technical competencies and budgets of the Teesside operators. The offshore pipeline is more akin to a high-pressure *transmission* system, with limited scope for phased development, potentially driven by CO₂ demand for EOR, with costs in the hundreds of millions – this lies closer to the technical and financial remit of major energy companies. In our view, this suggests a natural break in ownership between the two components, pivoted around the onshore coastal booster station.

Our analysis suggests that the onshore network could be promoted and developed by a ‘coalition of the willing’ made up of Teesside operators, via a JV consortium and using a project finance model (SPV). We consider that there is significant potential to build an appropriate vehicle through which to promote and develop the project, building on existing relationships and structures in the Tees Valley (e.g. the North East Process Industry Cluster; NEPIC) – to this end, ten NEPIC members have already signed up to a Collaboration Agreement – the Process Industry Carbon Capture and Storage Initiative (PICCSI) to further explore potential of a CCS network. This is the first small step in the process of moving towards a JV, as described previously.

At this stage of developments, the most effective strategy for Tees Valley operators probably involves building a robust business case – with associated estimates of costs and revenues, and the structure under which this could move forward – involved with delivering CO₂ to a coastal location at transmission pressure (i.e. with low impurities and pressure in the order of 180 bar). This could serve to “tease out” the views potential CO₂ takers offshore – presently these entities seem to be keeping their plans – if any – out of the public domain. Under this strategy, potential takers could then be left with the commercial choice on how they might want to valorise the CO₂ “asset” at the coast – either by shipping or through pipeline construction. This could help bring the two ends of the value chain together.

⁹⁴ CO₂sense Yorkshire. Commercial and financial structuring options for a CO₂ network in Yorkshire and Humber. Brochure/Executive Summary. 2009.

6.6 The role of the EU and UK Government

Whilst some initial ideas for moving the project forward have been outlined, risks still remain which cannot be resolved through these models alone (e.g. the lack of long-term 'bankable' incentives, the funding gap for different parts of the chain). Therefore – and as highlighted previously – there remains a role for Government in supporting this project. Teesside operators have made a first step by way of PICCSI. However, significantly clearer Government views on policy approaches and regulatory support mechanisms - carbon price guarantees, performance guarantees, soft loans, clarity on the potential for CCS in gas or industry (see Section 7) – are all still near-term imperatives that are essential before the project can move forward into the next phase of development. The opportunity exists for PICCSI (or other North East grouping) to shape these debates.

Neither a laissez faire nor a centrally planned approach is likely to deliver an optimal CCS network for the Tees Valley. The Government's support for integrated regional CO₂ transport infrastructure is mixed, but as stated does not currently imply funding for future-proofed infrastructure. Examination of options for project structuring reveals that the most stable approach is through a process that develops agreements between stakeholders in a stepwise manner (Joint Venture).

A special purpose vehicle (SPV) with project finance offers the greatest means to insulate risks across the CCS chain and leverage capital from the market. There may be benefits in separating the onshore and offshore pipeline networks business models, and tailoring these for distribution and transmission respectively, and allowing refinancing when most appropriate.

The clarification of CCS incentives and regulation by Government will be a pre-requisite to investment. A range of tariff structures may be developed to optimise the allocation of risks and rewards, although experience suggests it is unlikely that an independent regulator would be required to prevent monopoly abuses. A big uncertainty remains commercial appetite over CO₂-enhanced oil recovery.

7 Conclusions and Recommendations

The analysis presented in this report identifies that manufacturing and power industry within the Tees Valley are critical to the economy of the North East of England. The commercial viability of several of these businesses is threatened by increasing carbon prices and carbon regulation. This could result in these businesses relocating to countries with lower environmental regulation, resulting in severe impacts to the North East economy. Whilst this issue has been recognised by the Committee on Climate Change and UK Government, at present there does not appear to be a coherent national (or European) strategy to resolve this.

A CCS network offers the potential to transform the Tees Valley from an area threatened by tightening carbon regulation to a preferred location for European manufacturing industry and fossil and biomass power stations. A CCS network developed in the Tees Valley is technically feasible, could deliver up to 8% of the UK's required CO₂ reduction for 2030, and is already understood and has the support of several local stakeholders.

The average abatement cost of a 'Medium' sized CCS system connecting 8 point sources is estimated at ca. £48/t CO₂ abated. Of this, £7/t CO₂ is expected as a cost of service for use of a common transport network with a maximum capacity of 22 Mt CO₂/year. There are at least five possible candidates for CCS demonstration projects in the North East any of which could act as an anchor customer for a CCS network. A shared pipeline network reduces the cost to all users, potentially allowing some users to connect at marginal cost and difficulty.

The actual cost of service will depend on a range of inter-related factors. Demonstration funding, use of nearby sinks, favourable financing conditions and early connections of subsequent sources could each reduce network cost of service below £5/t CO₂. In contrast, reduced utilisation, long offshore pipelines or high risk premia could each drive cost of service above £10/t CO₂ which would likely render the network uneconomic. Combinations of factors obviously have a more profound impact on overall economics than individual factors alone. An agreement to purchase CO₂ by an oil company for use in CO₂-enhanced oil recovery would dramatically improve the economics of CO₂ pipeline, but enthusiasm for this within the oil industry under current market arrangements is limited.

The absence of a dominant source, and the existing experience for industrial emitters in sharing pipeline infrastructure suggests that economic regulation to avoid monopolistic practices may not be necessary. An 'Open Season', whereby existing emitters purchase capacity rights or tradable options, may be used by demonstration projects to leverage some private investment, although this will likely be very limited at this stage of technology maturity, regulatory clarity and with current carbon pricing signals. At present the capital markets are unlikely to provide debt finance. However, in the period up to and beyond 2020, the economic signals and legal requirements for carbon reduction are likely to become significantly clearer, which offers the potential to refinance initial investment at lower cost.

7.1 Barriers to delivering a North East CCS network

The key barrier identified in this study for the development of a North East CCS network is insufficient long-term clarity on policies, legislation, regulation, market incentives and social acceptance for the energy and climate sector in general, and on CCS specifically.

This is a systemic issue that affects all CCS networks in the UK and Europe and so can best be dealt with at the level of European and national Government.

In addition the North East region specifically faces additional barriers:

- Lack of credible independent examination of CO₂ storage options
- Insufficient organisation of stakeholders
- Diversity of CO₂ sources implies cross-industry coordination will be needed to develop an optimum common CO₂ entry specification for any pipeline.

Whilst not a barrier per se, improved public or political awareness and support for deployment of CCS in the North East or by large industrial or gas power sector CO₂ emitters could increase the likelihood that optimal choices become available in a timely manner.

7.2 Recommended actions to deliver a North East CCS network

Assuming stakeholders agree that CCS offers genuine opportunities to protect the North East economy from the threat of higher carbon prices and regulation, then considerable activity on the part of many stakeholders is required to remove the barriers to deployment of CCS infrastructure in the North East.

Many of these barriers are common to other places where CCS deployment is being considered. There are already a number of multi-stakeholder organisations examining energy, climate and CCS issues nationally and internationally. The UK Government and some of the companies in the North East are already involved in these activities and there is no requirement to duplicate this activity.

There is however a real opportunity for ONE⁹⁵/NEPIC stakeholders to protect value at risk in existing businesses in the Tees Valley and create new business opportunities by contributing in a coherent manner to policy development on CCS development, demonstration and deployment, including broader energy, industrial and climate policies.

Recommendation One – Improve organisation of stakeholders in a North East CCS network.

Recognising that regional partnerships in Scotland, Yorkshire, Rotterdam⁹⁶, and Northern Netherlands, have been efficient in monitoring, influencing and directing CCS technologies, markets and regulations to the benefit of their regional stakeholders, this report recommends that One North East (and successor organisations) and The North East Process Industries Cluster should seek to establish an appropriate organisational structure to monitor, influence and direct regional CCS deployment most efficiently. The recently formed PICCSI group represents an excellent start in this process.

One option to achieve this is to ensure the Tees Valley becomes a Low Carbon Economic Area for CCS.⁹⁷ Within this structure, the proposed level of organisation could be a 'North East CCS Task Force' and should ideally include:

⁹⁵ Or alternative strategic North East economic partnership or successor body.

⁹⁶ See for example <http://www.rotterdamclimateinitiative.nl> and <http://microsites.ccsnetwork.eu/rotterdamroad>

⁹⁷ This could provide a means of bringing together formally diver stakeholders that could impact the timing, likelihood and amount of investment (including BIS, DECC (primarily the Office for CCS but also the oil and gas division), HM Treasury, The Crown Estate, environmental NGOs, local population, European Commission, Ofgem, HSE, fuel suppliers, offshore industry and potential financiers).

- Private sector representatives from large existing and potential Tees Valley CO₂ emitters (and medium-sized emitters subject to interest).
- Public sector representatives with responsibilities for spatial and economic planning, climate and energy policy, and the regulatory frameworks for CO₂ capture, transport and storage.
- Potential providers of CO₂ capture, transport and storage facilities. (Oil companies interested in CO₂-EOR could also be included).

Recommendation Two – Use the improved organisation to assist the development of a CCS network.

Recognising that stakeholders will be impacted by international developments in climate, energy and CCS, the Organisation should *evaluate* the local impacts from:

- Global and European energy and climate policies.
- Global and North Sea Basin-related CCS technology and market developments. This would include RD&D, regulations, economics, social acceptance, regional initiatives, and health, safety and environmental aspects of CCS system design and operation.
- Legal impediments to commercial discussions between stakeholders and to CCS deployment.
- The ownership, strategies, or activities of key stakeholders and associations.

The Organisation should *influence* :

- The design of European, UK, North East and local policies, regulation and other initiatives for CO₂ capture from the coal, gas and industrial sectors and for CO₂ transport and storage infrastructure.
- Regional and local public and political opinion on CCS.
- The priorities of trade associations (e.g. CCSA, CIA).
- The priorities for UK and regional public and private CO₂ storage evaluation.
- National planning for energy, CCS and offshore infrastructure.

Further the Organisation should seek to act as a single point-of contact to *control* directly:

- Shared responses to Consultations.⁹⁸
- Marketing of a CCS network to wider stakeholders.
- Contractual commitments between stakeholders (e.g. emitters and transport company) to use network if available, to ensure these are compatible with wider objectives.
- The design specification of CO₂ transport and storage infrastructure (capacity, location, entry/exit specifications).
- Engagement with other regional CCS networks (for example in Scotland, Yorkshire and Rotterdam) on issues of common interest.

⁹⁸ See for example recent electricity market and CCS related consultations listed at <http://www.decc.gov.uk/en/content/cms/consultations/open/open.aspx> , the carbon floor price consultation available at http://www.hm-treasury.gov.uk/consult_carbon_price_support.htm and ongoing updates to national planning policy consultations such as <https://www.energyngpsconsultation.decc.gov.uk/docs/ConsultationDocument.pdf>

Any organisation should share lessons with others on stakeholder organisation⁹⁹, risk management and allocation, attracting investment, technical specification¹⁰⁰, and CCS costs and performance.

Recommendation Three – Provide key stakeholders with an independent, robust assessment of accessible CO₂ storage options.

Recognising that transport and storage costs and risks will depend on the storage site chosen, and that transparency will be critical to obtaining the necessary stakeholder support, this report recommends a continuation of efforts already underway to evaluate accessible CO₂ storage options.

Recommendation Four – Strengthen and support the commercial scale for a CCS anchor project and a CCS network in North East England.

Local stakeholders should critically review, strengthen and where appropriate, strongly promote proposals for CCS demonstration projects to be located in the North East of England and the overall business case for a CCS network. This will ensure suitable network anchor projects are seen as viable in delivering all the objectives of CCS demonstration *and* have the support of stakeholders making them realistic candidates to nucleate a CCS network.

Recommendation Five – Include CCS within planning policies.

Continue to examine opportunities to reduce costs and barriers through the optimal inclusion of CCS infrastructure requirements within national and local planning policies. This could include updating further the North South Tees Industrial Development Framework to safeguard further potential rights of way identified for potential CO₂ pipelines.

Recommendation Six – Explore public/NGO support for CCS deployment in the Tees Valley.

Consider a pilot public/NGO engagement study to understand social drivers and barriers for CCS deployment in Teesside.

Recommendation Seven – Continue to support other options for CO₂ reduction.

Recognising that reducing the amount of CO₂ to collect will reduce absolute costs for capture, transport and storage, Tees Valley CO₂ emitters will still need to continue to examine all opportunities for reducing CO₂ emissions and share their forecast emissions where possible.

Recommendation Eight – Examine the impacts of pipeline entry specifications on the costs and feasibility of CO₂ capture and compression for North East emitters and potential storage operations.

Recognising that the entry specification for any transport network may influence capture and storage investments, the Task Force should ensure key stakeholders are fully informed as to the impacts of choices, to ensure system-wide benefits are not threatened.

⁹⁹ See for example Yorkshire Forward's CCS network, Scotland, Rotterdam and the ZEP Task Force.

¹⁰⁰ As an example, DNV's Pipetrans phase project examines common entry specification for CO₂ pipelines.

Participation in international programmes would ensure stakeholders are up-to-date with technology development.

A suggested timeline for implementing the steps needed to deliver a joint venture is described below in Figure 19.

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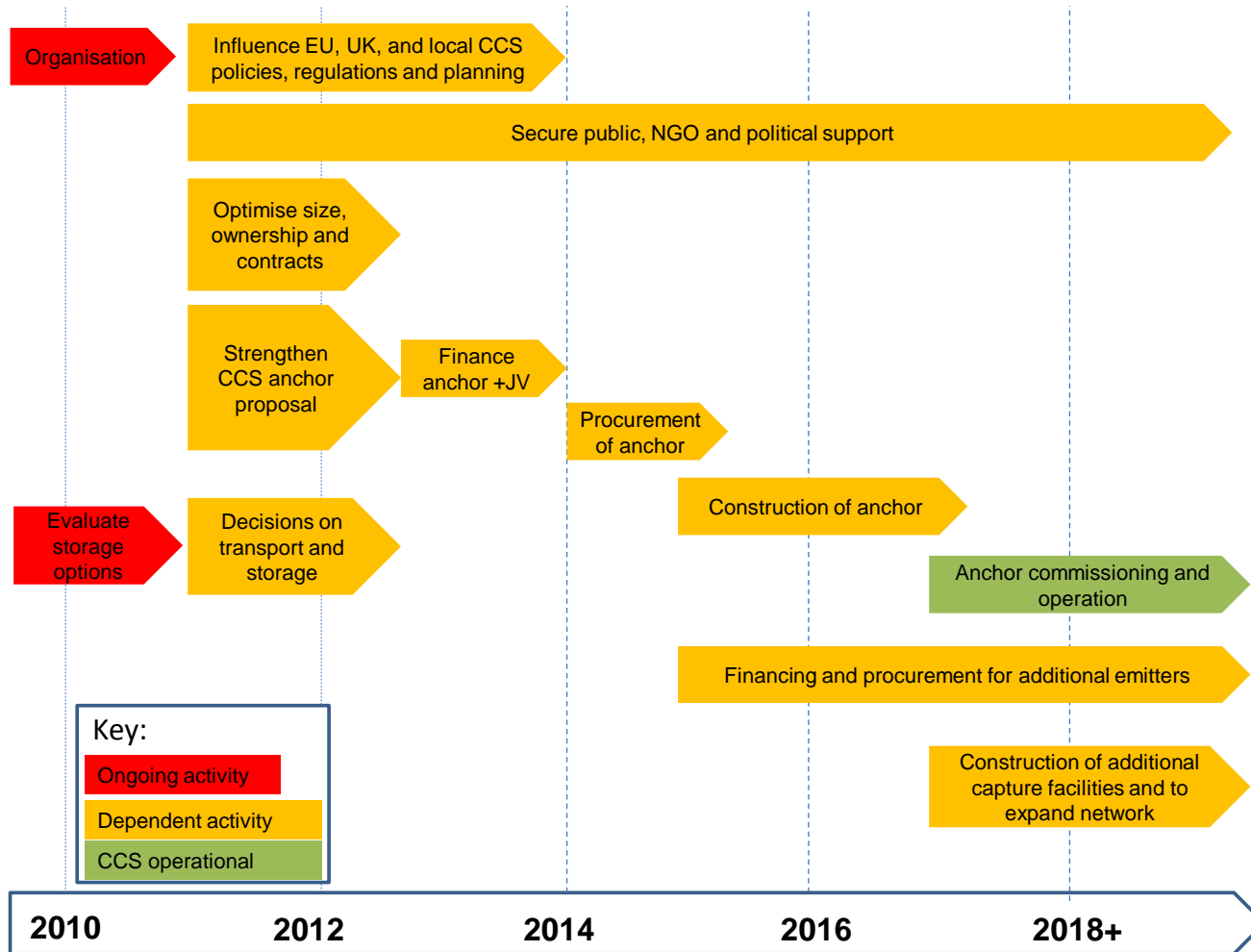


Figure 19 Timeline for potential development of a joint venture for a CCS network in the Tees Valley.

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GdF Suez	Simon Storage
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