The Economic Impact of Developing a CCS Network in the Tees Valley

A report for Tees Valley Unlimited

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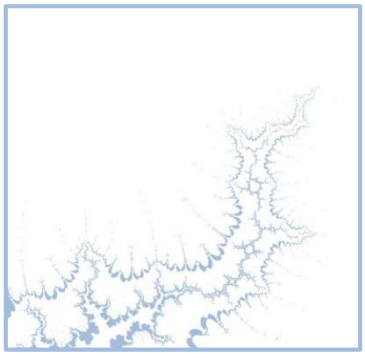
Cambridge Econometrics
Covent Garden
Cambridge
CB1 2HT
UK

01223 533100
sb@camecon.com
www.camecon.com



Authorisation and Version History

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3.0	19/06/2015	Mike May-Gillings	Final report.
2.0	27/05/2015	Mike May-Gillings	Draft final report.
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Executive Summary

Background

The Tees Valley represents one of the largest clusters of manufacturing industries in the UK. Industries in this region contribute over £10bn to GVA annually and provide over 25,000 manufacturing jobs in the local area.[1][2] The industries in the Tees Valley produce a significant share of the UK's manufacturing output and account for 25% of GVA in the North East of England.[3]

Industries in this region emit around 20 $MtCO_2$ pa (equivalent to 22% of total emissions from manufacturing industries in the UK). The energy-intensive industries located in the Tees Valley are, therefore, particularly vulnerable to a high carbon price, which could adversely affect their competitive position in global markets. Industrial Carbon Capture and Storage (CCS) has the potential to protect energy-intensive industry from a high carbon price in the future, whilst also curtailing CO_2 emissions in the UK.

The Tees Valley is often cited as the prime location for developing a CCS network in the UK. Located close to the North Sea coast, the Tees Valley has good access to a range of offshore CO_2 storage options and the cost of transporting CO_2 offshore is relatively low.[4] The manufacturing plants within the Tees Valley are also concentrated within a small area (of around 2,600 hectares), which reduces the capital cost of constructing the CCS network and transporting CO_2 within the onshore network.[5]

Summary of analysis

Cambridge Econometrics was commissioned by Tees Valley Unlimited to assess the likely economic impacts of developing a CCS network in the Tees Valley. This work formed part of a wider set of studies funded by the Department of Energy and Climate Change (DECC), in collaboration with the Department for Business Innovation and Skills (BIS), on the potential for developing a CCS network in the region.

The analysis that is presented in this report involved considering the likely effects on economic activity and employment in the Tees Valley region and the wider UK economy, as a result of:

a) the construction and operation of a 15 $MtCO_2$ pa CCS network in the Tees Valley;

b) retaining existing energy-intensive industry that might otherwise leave the Tees Valley region if the carbon price increases further;

c) attracting new energy-intensive industries to the CCS network in order to reduce their carbon costs.

It is important to note that this analysis only takes account of the gross effects of the construction and operation of the CCS network and the economic value of the industries that connect to the network. We implicitly assume that the

[1] Carbon Capture and Storage Association (2015), available online at: http://www.ccsassociation.org/about-us/our-members/tees-valley-unlimited/
[2] Orion Innovations (2013), 'A UK Vision for Carbon Capture and Storage'
[3] Orion Innovations (2013), 'A UK Vision for Carbon Capture and Storage'
[4] Element Energy (2010), 'Developing a CCS network in the Tees Valley Region'
[5] Element Energy (2010), 'Developing a CCS network in the Tees Valley Region'

project is financed by government subsidies and do not take account of the trade-off for government, for example, if the cost of the CCS network displaces financing of investment on alternative projects, or if taxes were increased to pay for the investment cost.

Economic Results

The key results are summarised in the table below.

	Jobs supported (number)	Annual GVA (£bn)	Annual gross exports (£bn)
Construction of CCS network (2021-2024)	1,200 ST jobs* 350 LT jobs	£0.1bn*	-
Extension of CCS network and construction of new plants (2025-2030)	5,000 ST jobs* 700 LT jobs	£0.4bn*	-
Industries that initially connect to network in 2025	2,400 direct (0.7%) 3,500 indirect	£0.3bn direct (1.6%) £0.4bn indirect	£0.7bn
Industries that connect to network post-2025 (illustrative)	1,100 direct (0.3%) 1,500 indirect	£1.0bn direct (5.5%) £1.2bn indirect	£1.2bn

Note: Jobs and GVA estimates include direct and indirect effects. Figures in parenthesis show jobs and GVA as a share of total in Tees Valley region. Post-2025 industries are mainly chemicals process plants with high labour productivity, hence the high GVA/jobs ratio.
* Short term jobs and GVA in a peak construction year over specified period.

The economic analysis shows that developing a CCS network in the Tees Valley could support over 1,000 direct and indirect short-term jobs in the UK during the 4-year construction period (2021-2024 inclusive), and a further 350 long-term jobs, directly and indirectly associated with the operation and maintenance of the CCS network (refer to Section 1).

The development of the CCS network itself would lead to an annual increase of around £85m in GVA in the UK over 2021-2024. This includes a £30m annual increase in direct value added to the region; a further £20m annual increase in direct value added to the rest of the UK; and an additional £35m increase in value added in the UK due to indirect effects.

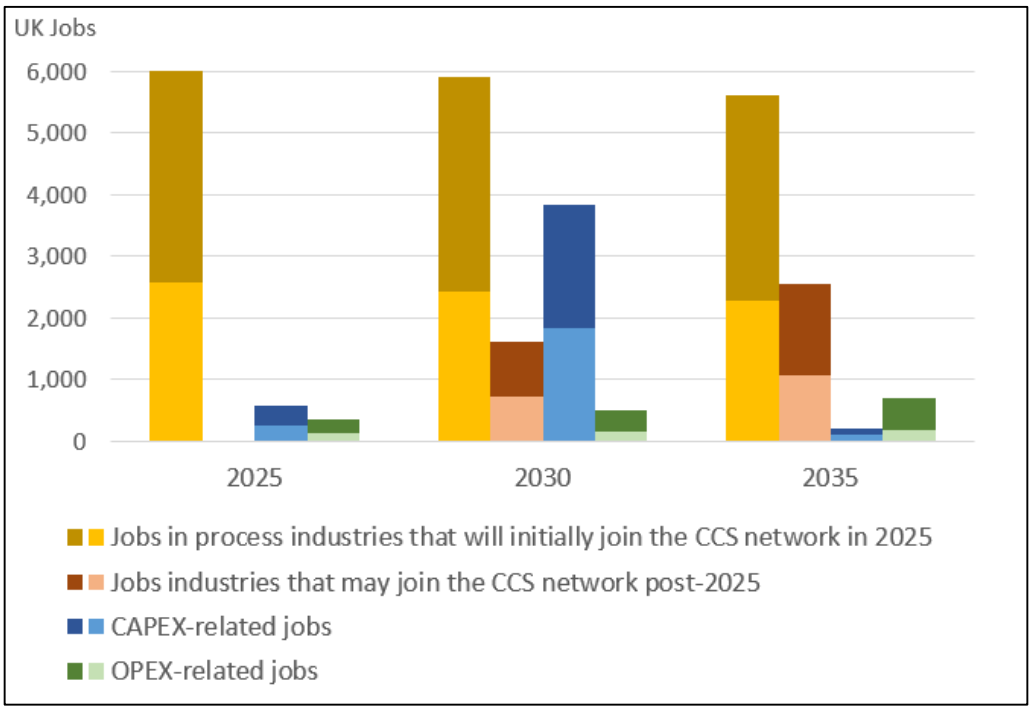
Four companies in the region operating energy intensive process plants have already expressed an interest in joining the CCS network (SSI, Lotte, Growhow, BOC Linde). As is typical of the energy intensive sector, they foresee facing a carbon constrained future and are looking for ways in which they can reduce their emissions whilst remaining competitive and keeping manufacturing in the Tees Valley. Retaining these industries within the Tees Valley in the long-term would have a significant positive benefit for the local area. After taking account of expected productivity improvements it is estimated that, by 2030, these industries combined will directly employ 2,400 people, and will support an additional 3,500 jobs in their UK-based supply chains. It is also estimated that they will directly contribute around £290m in

GVA and indirectly contribute to around £400m GVA in their associated supply chains.

The planned CCS network has a total capacity of 15MtCO_2 pa. After accounting for the four companies who have already expressed an interest in joining the network, there is 12.2 MtCO_2 capacity available for new CCS-equipped plants to join the network post-2025. If new plants are attracted to the Tees Valley because of the CCS network, this could lead to a further boost to local inward investment and employment. The construction of the new CCS-equipped plants and their connection to the CO_2 network could lead to a £450m increase in direct and indirect GVA and create around 5,000 additional direct and indirect jobs in 2029, a peak construction year.

The plants themselves could support further employment opportunities in the local area. In our illustrative scenario, new CCS-equipped plants that might be attracted to the site could directly support 1,100 jobs by 2035, and an additional 1,500 jobs in their supply chains. It is to be noted that this is a conservative estimate; due to plant capacity constraints, we assume that high growth in labour productivity (of around 5% per annum for the chemicals process plants) reduces employment, instead of leading to real increases in economic output and GVA over the period to 2035. In reality, it is likely that innovations in the sector will lead to real increases in the productive capacity of the plants, and therefore real output and employment in these industries would be higher than we have estimated.

Jobs supported by the construction of a CCS network in the Tees Valley



Note: Light shading represents direct jobs; dark shading represents indirect jobs. 'CAPEX-related jobs' includes jobs in the construction of the CCS network and the construction of new plants. 'OPEX- related' jobs includes jobs in the operation of the capture plant and transportation and storage network. Fluctuation in the short-term CAPEX jobs coincides with years of peak construction of the network and CCS-equipped plants. In 2025 and 2035, site construction activity is relatively low compared to in intermediate years.

Reporting conventions

All monetary values in this report are expressed in pound sterling (£) and in real 2014 prices. The employment results are expressed as Full Time Equivalent (FTE) jobs. Jobs are described as being *supported* in cases where they are a direct consequence of government investment expenditure. However, it is noted that inward investment in plants that are attracted to the Tees Valley because of the CCS network could *create* further jobs in the UK.

1 Developing a CCS Network in the Tees Valley

This section of the report presents our analysis of the direct and indirect effects associated with the construction and operation of a CCS network in the Tees Valley. A network with 15MtCO_2 capacity was chosen for the economic analysis as it is the most cost-effective option (per tonne CO_2 captured), of those considered by TVU, as there is more potential to benefit from economies of scale in the construction and operation of the network. The positive economic effects associated with a smaller 5MtCO_2 network would be somewhat lower, particularly as the CO_2 capacity constraint would substantially reduce the potential for new industries to join the network. Detailed information about the analytical methodology used is available in the appendices to this report.

1.1 Impact on GVA

Construction of the CCS network

The economic analysis shows that during peak construction years (2021-2024), the construction of the CCS network would lead to an £85m annual increase in GVA. Our analysis shows that there would be a £30m annual increase in direct GVA in the Tees Valley region, of which around 30% is in the construction industries and a further 7% in local manufacturing industries. The development of the network is estimated to lead to a further £20m increase in direct GVA in other regions of the UK. The increase in output from UK-based companies that are directly involved in developing, manufacturing and constructing the CCS network would lead to a further increase in demand and economic output in the supply chain associated with these industries. The multiplier effects in our analysis are taken from ONS Input-Output tables[6] and imply an increase of about £0.7m in indirect economic output, for each £1m increase in direct output in the UK. This implies that there is an indirect annual increase in GVA of £35m in this initial investment phase, running from 2021-2024.

The location of the supply chain for the CCS equipment is important. The total capital cost of the materials and equipment for the CCS network amounts to £345m, but only 20% of the economic value associated with manufacturing this equipment is assumed to be retained within the UK, with a large proportion of the required materials and equipment imported from abroad. As would be expected, a much larger proportion (95%) of the construction-related investment activities, which amounts to about £50m, is assumed to be retained within the UK. Investment in engineering and management related activities is also assumed to have a high domestic supply chain content, with 60% of spending being spent within the UK[7].

As shown in Table A.2 in Appendix A, GVA multipliers from the ONS Input-Output tables were used to calculate associated indirect GVA impacts of the capital expenditure. During the peak investment period, capital expenditure

[6] See Table A.2 in Appendix A for detailed economic assumptions.
[7] See Table A.1 in Appendix A for detailed supply chain content assumptions.

from the construction of the CCS network would lead to an annual increase in GVA of about £35m in the UK as a whole due to indirect effects.

Overall, the economic analysis shows that during peak construction years the construction of the CCS network would lead to an annual total increase in direct and indirect GVA of about £85m in the UK as a whole. A sensitivity was tested, in which the proportion of domestic suppliers of the engineering and management services was higher, at 80% (compared to 60% in the baseline). This led to a further £5m increase in UK GVA.

Operation and maintenance of the CCS Network

After the initial construction of the CCS network, there would be further fixed and variable costs linked with the operation and maintenance of the CCS network, and therefore associated direct and indirect GVA impacts. The main sectors that would be directly affected by the operation and maintenance of the network would be:

- Electricity, gas, steam and air conditioning supply
- Office administrative, office support and other business support activities
- Repair and installation of machinery and equipment
- Insurance, reinsurance and pension funding

It is estimated that the fixed costs of operating and maintaining the network for the existing industries alone would lead to a direct annual GVA increase of £15m in the Tees Valley Region, particularly associated with maintenance and insurance. Using GVA multipliers from ONS Input-Output tables and estimates of variable power and steam costs for the existing industries[8], it is estimated that there would be an additional £35m annual increase in GVA in the UK as a whole due to indirect effects of operating and maintaining the network for the existing industries.

Table 1.1: GVA impacts associated with OPEX for initial CCS network (£m)

OPEX Cost Type	Direct GVA	Indirect GVA
Fixed		
Direct Labour	0.4	0.8
Admin/overheads	0.2	0.1
Maintenance	6.7	5.9
Insurance	7.9	9.3
Variable		
Power and steam	-	18.5

1.2 Impact on employment

Construction of the CCS network

The economic analysis shows that the initial investment phase (2021-25), including the construction of an onshore CCS network, connecting the four

[8] See Table A.3 in Appendix A for detailed economic OPEX assumptions.

process plants to the network, and transportation and storage of CO_2 offshore, would support 400-500 short-term jobs in the UK as a whole (of which 200-300 are expected to be in the Tees Valley). An additional 600-700 indirect jobs in the associated supply chain would be supported during the construction period (see Figure 1.1 and Figure 1.2).

The effect of capital expenditure on employment is estimated using assumptions from the Annual Business Survey about the labour intensity of output for each sector of each capital cost component[9]. Labour intensity in the construction sector is relatively high, resulting in relatively high employment impacts per £m of capital expenditure. During peak construction years, total CAPEX spending in construction of about £50m is expected to support about 100 construction jobs, compared to about 200 Mechanical, Instruments & Electrical related jobs supported from spending of over £350m in the sector.

As outlined in Table A.2 in Appendix A, employment multipliers from the ONS Input-Output tables were used to calculate associated indirect employment impacts of the capital expenditure. During the peak investment period, capital expenditure from the construction of the CCS network would support about 700 jobs in the UK as a whole due to indirect effects, many of which would be from the supply chain associated with spending in Offshore Pipework.

Operation and maintenance of the CCS Network

It is estimated that the fixed costs of operating and maintaining the network for the existing industries alone would support about 100 direct long-term jobs (post-2025) in the Tees Valley Region, particularly in maintenance and insurance. Applying employment multipliers from ONS Input-Output tables[10] it is estimated that an additional 200 jobs would be supported in the UK as a whole due to indirect effects of operating and maintaining the network for the existing industries.

Based on a report by AMEC Foster Wheeler/RHi[11] it is estimated that there will be about 20 people directly employed to manage and/or operate the CCS network, which is likely to support an additional 30 jobs due to indirect effects. The majority of direct employment, however, will be in maintenance and insurance related jobs (over 80%).

Table 1.2: Employment impacts associated with OPEX for initial CCS network (jobs)

OPEX Cost Type	Direct jobs	Indirect jobs
Fixed		
Direct Labour	18	32
Admin/overheads	3	4
Maintenance	94	72
Insurance	24	28
Variable		
Power and steam	-	73

[9] See Table A.2 in Appendix A for detailed economic assumptions.
[10] See Table A.3 in Appendix A for detailed economic OPEX assumptions.
[11] AMEC Foster Wheeler/RHi report: Cost Estimate report for Tees Valley Unlimited, March 2015

Figure 1.1 Jobs supported in Teeside and the UK due to the construction of a CCS network over the period 2021-2024

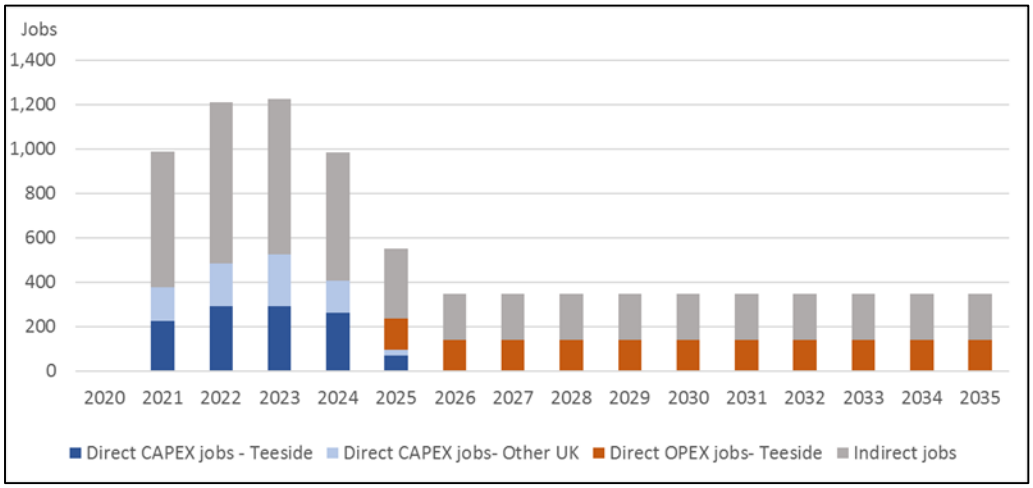
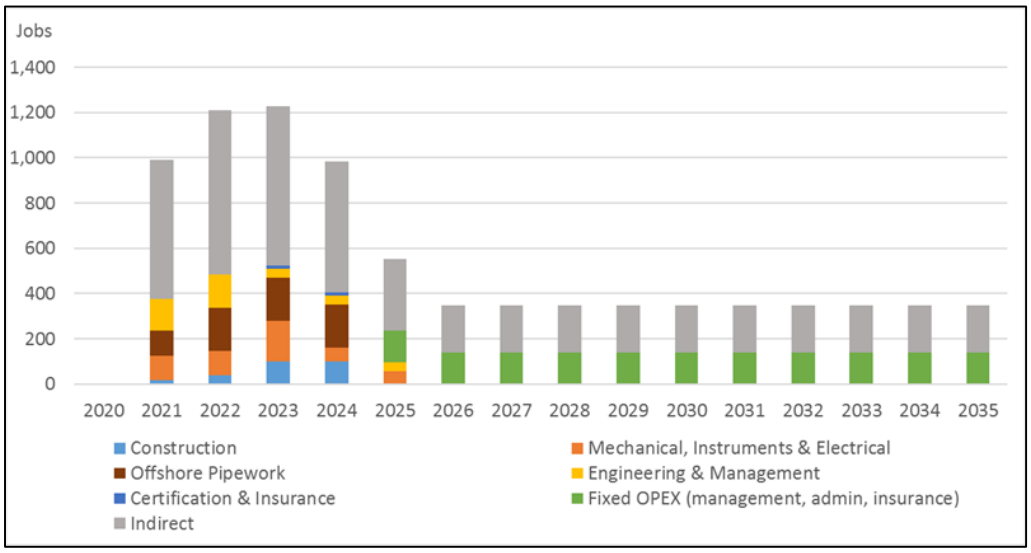


Figure 1.2 Jobs supported (by sector) due to the construction of a CCS network over the period 2021-2024



2 Retaining existing industry in the Tees Valley

There are four existing operations in the Tees Valley (SSI, Lotte, Growhow, BOC Linde) that have become founder members of the Teesside Collective initiative, which seeks to promote the development of an industrial CCS network. Clearly they, and other similar companies, face the challenge of competing with companies operating in regions with looser environmental regulations. This section of the report presents our analysis of the value of these four operations to the local economy in the Tees Valley and hence why maintaining their manufacturing activity is important.

2.1 GVA in industries that initially join the CCS network

GVA in the four plants that could initially be connected to the CCS network was estimated based on current employment and turnover figures and detailed economic statistics from the ONS[12]. Combined turnover from the firms' Teesside operations in 2014 amounted to over £1.7bn and it is estimated that they directly contribute around £290m in GVA and indirectly contribute around £400m GVA in their associated supply chains. We have assumed that the plants are effectively running at full capacity throughout the period. This implies that no significant real increase in economic output or value added over the period to 2030 in these plants that are initially connect to the network is possible.

2.2 Employment in industries that initially join the CCS network

The four process plants that have already expressed interest in connecting to the CCS network provided current employment figures. We used projections of labour productivity growth[13] in each of these industries to estimate the future employment in these four process plants.

In aggregate, the four operations in Teesside supported around 2,940 local jobs at the start of 2015, and it is estimated that activity from these plants support a further 4,170 jobs in these industries' supply chains in the UK.

The chemicals sector in Teesside is significantly more productive than similar industries elsewhere in the UK. Plants located in this cluster benefit from economies of scale: they have access to shared knowledge and infrastructure and are located close to key suppliers of material inputs, which reduces transportation costs. Our economic forecast suggests that there will continue to be high productivity growth in the North East chemicals sector (of around 5% pa), due to the continued development of technologies that automate and improve the production process. This will lead to a slightly lower employment ratio in these industries in the long term. By 2030, we expect these plants to support 2,400 direct jobs and 3,500 indirect jobs.

[12] ONS Annual Business Survey 2013. Available online at: http://www.ons.gov.uk/ons/publications/re-reference-tables.html?edition=tcm%3A77-341896

[13] Regional sectoral labour productivity growth estimates were taken from Cambridge Econometrics (2015).

3 Attracting new industries to the Tees Valley

The capacity of the CCS network considered for this analysis is 15 $MtCO_2$. Assuming that only the SSI, Lotte, Growhow and BOC Linde plants (with combined CO_2 emissions of 2.8 $MtCO_2$ pa) are initially connected to the CCS network, this would leave 12.2 $MtCO_2$ pa additional capacity for new CCS equipped plants to join the network and provide a low carbon manufacturing cluster.

The results presented in this section of the report represent the economic contribution of additional industries that may be attracted to the Tees Valley CCS network. There are various possibilities for different energy-intensive industries to join the Tees Valley CCS network after it is built, and there is some degree of uncertainty about the characteristics of the industries that will ultimately join the network and whether they re-locate from within or outside of the UK. This analysis quantifies the economic impact of attracting to the Tees Valley new investments in the form of additional process chemical manufacture, novel technology in the shape of a low carbon cement operation, and a coal IGCC power plant with post-combustion CCS as well as decarbonising existing activities such as oil & gas processing. The results in this section are intended purely to illustrate the opportunity for establishing a low-carbon cluster in the Tees Valley and, as these industries are only representative of one possible combination of CCS-equipped plants joining the network, the results should be interpreted as indicative.

3.1 Capital investment in new plants that join the CCS network

To calculate the effects of the new industries that join the network, the capital cost of building and connecting the plants to the CCS network was estimated, based on analysis for similar plants (as presented in the AMEC Foster Wheeler/RHi report[14]), and an estimate of the required extension to the network of CO_2 transportation pipeline. Information about the industries that are assumed to join the network, including emissions and the cost of constructing the CCS-equipped plant (or retrofitting installations to enable CCS) are shown in Table 3.1 below.

Table 3.1: Characteristics and capital cost of CCS installations

	Emissions ($KtCO_2$ pa)	Capital cost (£m)	Construction period
Retrofit SSI	1,600	300	2021-2025
Retrofit Lotte	50	35	2021-2025
Retrofit Growhow	375	28	2021-2025
Retrofit BOC Linde	300	55	2021-2025

[14] Rider Hunt International (2015) 'Cost Estimate Report for Tees Valley Unlimited: Work Package 7, Whole Project Cost Estimating'.

	Emissions ($KtCO_2$ pa)	Capital cost (£m)	Construction period
New coal IGCC CCS power plant	5,000	1,500	2026-2030
CCS retrofit ammonia production plant	500	50	2025-2029
CCS-equipped ammonia production plant	875	420	2028-2032
CCS retrofit existing oil processing plant	300	50	2026-2030
CCS retrofit four existing chemicals plant	1,000	200	2025-2029
New CCS-equipped chemicals plant	875	750	2026-2030
New CCS-equipped cement plant	4,150	600	2031-2035
Onshore transport plus compressor	-	75	2021-2025
Offshore transport infrastructure	-	230	2021-2025
Additional onshore CCS network	-	75	2026-2030

A set of investment projections were formed which are indicative of how the CCS network could develop over the period to 2035. These five illustrative phases of investment are as follows:

- Phase A (2021-2025) – Construction of onshore CCS network, offshore CO_2 transportation and storage and connection of four existing operations in Teesside
- Phase B (2025-2029) – Expansion of CCS network and connection of a number of additional chemicals plants that are already located in Teeside
- Phase C (2026-2030) – Construction of a coal IGCC CCS-equipped power plant and an additional CCS-equipped chemicals plant. Connection of an oil processing plant to the CCS network.
- Phase D (2028-2032) – Construction of a new CCS-equipped chemical plant
- Phase E (2031-2035) – Construction of a new CCS-equipped cement plant

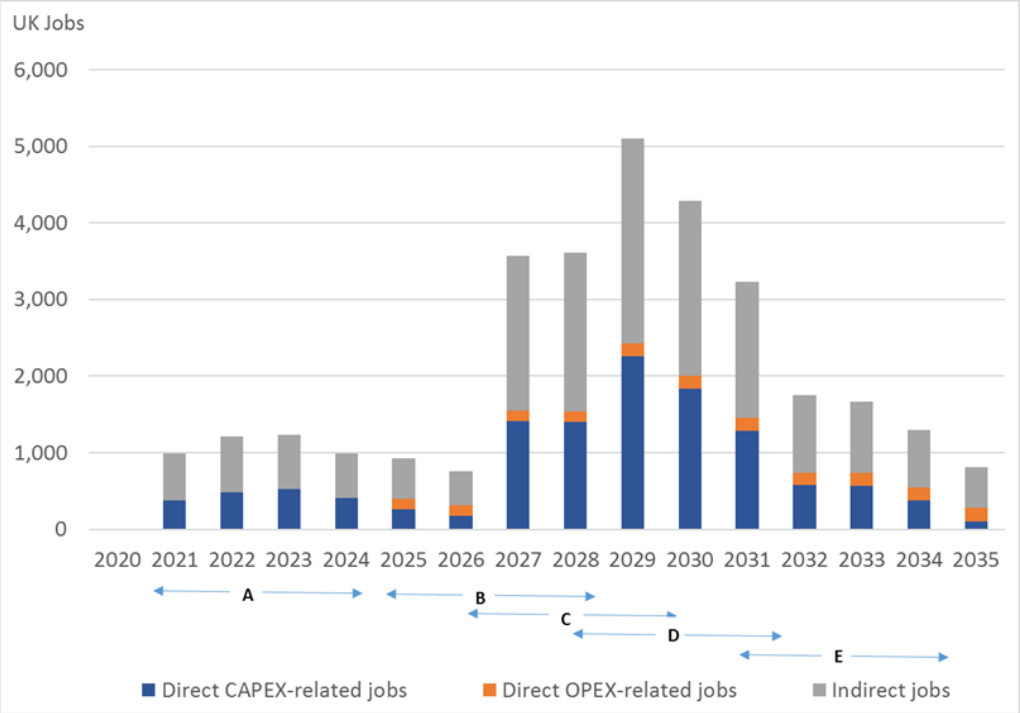
The results from the first phase of investment (2021-2025) are presented in Section 1 of this report. Attracting new CCS-equipped process plants to the area after the network is built will prolong the investment stimulus and lead to a more sustained increase in demand for local construction services. Connecting new CCS-equipped plants to the CCS network will create further economic benefits in the operation and maintenance of the expanded network.

Figure 3.1 shows that the investment stimulus brought about by the CCS network and the attraction of new industrial CCS-equipped plants to the region could create around 5,000 direct and indirect CAPEX-related jobs in a peak year and a further 700 direct and indirect long-term O&M jobs. Around 65% of the new direct jobs supported are expected to be in the Tees Valley.

The construction and operation of CCS-equipped industrial and power plants is estimated to lead to a £350m increase in GVA in a peak year. This includes a direct increase in GVA of £100m in Teesside and a £200m direct increase in

GVA for the UK as a whole. There would be an additional (indirect) increase in GVA of £150m, due to an increase in demand in these sectors' supply chains.

Figure 3.1 Jobs in the construction and operations of the expanded CCS network over the five defined investment phases



3.2 Economic contribution from new industries that join the CCS network

Attracting these industries to the area will not only create an investment stimulus when the plants are constructed, but could also generate long-term employment opportunities within those industries and create a further boost to the local economy.

If the CCS network develops in a similar way as in our illustrative scenario, the CCS network could support a number of manufacturing plants, with combined employment of 1,100 people and GVA of over £1.5bn. A further 1,500 jobs could be supported in these industries' supply chains. This is a conservative estimate based on the assumption that the productive capacity of the process industries is constrained. Therefore high expected productivity growth in these sectors over the period to 2035 is assumed to lead to a fall in employment and no real increase in economic output from these process industries.

The CCS network also has the potential to generate an increase in exports, from the new industries attracted to the Tees Valley, providing a further boost to the regional and national manufacturing sectors. The contribution these industries could make to the UK's export market was estimated using UK-level sectoral trade data[15]. If the CCS network develops in a similar way as in our illustrative scenario, exports from new industries that join the network are estimated to be in the region of £1.2bn annually.

[15] See Table A.4 in Appendix A for detailed UK GVA and exports assumptions.

4 Conclusions

Under the EU Emissions Trading System (ETS), installations require carbon allowances for each tonne of carbon emitted from industrial activities: a more ambitious commitment to reducing emissions in the EU, particularly following climate negotiations at COP 21 this year, could put upward pressure on the carbon price and affect the competitiveness of UK manufacturing industries in the EU ETS.

If there is a global climate change agreement that leads to a high global carbon price (or if there are sufficiently high government subsidies), then the opportunities that the CCS network provides in terms of reducing emissions and carbon costs for energy-intensive industry is likely to create a strong incentive for new process plants to re-locate to the Tees Valley and join the CCS network. The construction and operation of a CCS network in the Tees Valley could create a boost to the local economy in the North-East and attract energy-intensive manufacturing industry to the UK, in the context of a carbon constrained future.

4.1 Results from the quantitative economic analysis

An industrial CCS network in the Tees Valley allows low-carbon manufacture of important materials that are required to support the development of a low-carbon economy. This could prove to be a significant differentiator for the region in attracting investors. It will also provide a location for testing large scale low-carbon manufacturing technologies and will support further low-carbon energy generation projects. Our analysis finds that, in addition to the environmental benefits and the opportunities for the process industries themselves, the development of a CCS network could boost GVA and employment in the local area over the construction and operating period.

The results of our analysis suggest that:

- Developing a CCS network in the Tees Valley could support over 1,000 direct and indirect short-term jobs in the UK during the 4-year construction period (2021-2024 inclusive), and a further 350 long-term jobs, directly and indirectly associated with the operation and maintenance of the CCS network. The initial construction phase for the CCS network could also lead to an £85m increase in GVA annually in the UK over the period 2021-2024.
- The value of retaining the four companies that have already expressed an interest in joining the CCS network is significant. After taking account of expected productivity improvements it is likely that, by 2030, these industries, combined, will directly employ 2,400 people, and in the same year are estimated to support an additional 3,500 jobs in their UK-based supply chains. It is also estimated that they will directly contribute around £290m to GVA and indirectly contribute around £400m to GVA in their associated supply chains.

- If new plants are attracted to the Tees Valley because of the CCS network, this could lead to a further boost to local investment. The construction of the new CCS-equipped plants and their connection to the CO_2 network could lead to a £450m increase in direct and indirect GVA and create around 5,000 additional direct and indirect jobs in 2029, a peak construction year under our assumptions.
- The new CCS-equipped plants could themselves support further employment opportunities in the local area. In our illustrative scenario, new plants that might be attracted to the site could directly support 1,100 jobs by 2035, and an additional 1,500 jobs in their supply chains.
- The CCS network also provides industry with a competitive edge in the context of a carbon constrained future. For the indicative scenario described in Section 3, it is estimated that new plants attracted to the site could contribute £1.2bn in exports by 2035, in addition to an estimated £0.7bn in exports from the four plants that have expressed interest in joining the CCS network over the period 2020-2025.
- In addition to the economic benefits listed above, the CCS network, with a capacity of 15MtCO_2, could also play a significant role in reducing UK industrial emissions to meet domestic and EU emissions targets.

Whilst there are clear economic benefits related to the development of the CCS network, for the interpretation of our quantitative results, it is important to be aware of key limitations to our analysis. Most notably, our results represent the gross impacts of developing the CCS network. We have considered the value of the CCS-equipped industries that are likely to be connected to the network and have calculated the economic effects of the investment stimulus, but we have assumed that the cost of the network is financed by the government and have not considered the effects of higher taxes, higher borrowing or reductions in government expenditure that would be required to finance this project.[16]

4.2 Other potential economic effects

In addition to the quantitative effects described above, there are further positive effects associated with the deployment of industrial CCS in the Tees Valley, which were not explored within the scope of this study.

First-mover advantage

The Tees Valley could be used as a blue-print for future development of CCS technology in the UK and, if the UK is seen as actively interested in increasing deployment of CCS technologies over the coming decades, there are possibilities to benefit from first-mover advantage. This could come about as more of the CCS equipment manufacturers may decide to locate to the UK, to be closer to the market, leading to increases in economic output and GDP. Industrial CCS projects that are commissioned later may benefit from second mover advantage, but the associated cost savings from delaying commissioning are likely to be small: the technology is already well-developed and the specific design of an industrial CCS network is likely to vary

[16] Other key assumptions and limitations of our analysis are discussed in Appendix A.

substantially between sites, limiting the effect of transferable learning and economies of scale to reduce future capital costs[17].

Spillover effects

There is also potential for spill over effects in related industries as increases in R&D expenditure in the CCS sector could lead to innovations and technological improvements that benefit other sectors of the economy. Increased investment in CCS could also improve the skill-set of the local workforce who are employed in the construction and operation of the CCS network or in the CCS-equipped industries that connect to the network.

Spatially rebalancing the UK economy

Furthermore, creating a hub of investment and industrial activity in the North-East is particularly beneficial from a socio-economic perspective, as it could contribute to rebalancing growth within the UK. In the first quarter of 2015, the unemployment rate in the North-East of England was 7.5%, compared to 5.6% for the UK as a whole[18]. Improving employment opportunities in the North-East are therefore likely to have a more substantive economic impact than that for the average region of the UK: there is currently more spare capacity in the North-East labour force and so increases in employment are likely to lead to greater real economic effects rather than putting upward pressure on wages and prices. Furthermore, it could reduce the problem of unemployment hysteresis in the local area, the phenomenon by which prolonged unemployment has a permanent impact on individuals' employment prospects.

Enhanced oil recovery

In addition to the benefits described above, CCS also provides an opportunity for Enhanced Oil Recovery (EOR), as CO2 is injected into oil mature reservoirs, leading to increases in oil production in the UK, which could bring further economic benefits and increase government tax revenues.

[17] In their report titled, 'Strategic Analysis of the Global Status of Carbon Capture and Storage: Report 2', the Global CCS Institute indicate that there is likely to be only a small reduction (of around 10%) in the cost of Nth of a Kind (NOAK) industrial CCS technology, relative to First of a Kind (FOAK), due to the removal of process contingency costs applied to the capture technology.

[18] ONS Regional Labour Force Survey

Appendices

Appendix A Analytical approach and assumptions

Our analytical approach combined economic data about the characteristics of the industries that will develop, operate and join the CCS network, with analysis of the capital investment cost of developing and constructing the CCS network from a technical assessment by AMEC Foster Wheeler and RHi.

Inputs The key inputs to our analysis include:

- output, value added and employment data at a detailed sectoral level from the ONS Annual Business Survey[19]
- output and employment multipliers for each sector directly affected by the CCS network from the ONS Analytical Input-Output Tables[20]
- estimates of the CAPEX and OPEX costs of developing the CCS network from AMEC Foster Wheeler and RHi[21]
- assumptions about the local content of the supply chain for the CCS network, which were developed and checked by experts in the engineering industry
- assumptions about the characteristics of the new plants that are likely to be attracted to the CCS network

Approach To estimate the economic effects of capital investment in the CCS network, assumptions were made about the locally produced share of the upfront construction, installation and manufacturing costs (as shown in Table A.1). These assumptions were then applied to detailed cost estimates for the CCS network.

Table A.1: Domestic and import share of capital investment goods

Capital cost component	Local share	Other UK share	Imported share
Civils	60%	35%	5%
Mechanical, Instruments & Electrical	5%	15%	80%
Commissioning	60%	35%	5%
Offshore	60%	35%	5%
Engineering & Management	50%	10%	40%
Certification & Insurance	60%	35%	5%

For each capital cost component, GVA was calculated based on detailed sectoral data from the Annual Business Survey and GVA multipliers form the

[19] ONS Annual Business Survey 2013. Available online at: http://www.ons.gov.uk/ons/publications/re-reference-tables.html?edition=tcm%3A77-341896
[20] ONS UK Input-Output Analytical Tables 2010. Available online at: http://www.ons.gov.uk/ons/publications/re-reference-tables.html?edition=tcm%3A77-346757
[21] Rider Hunt International (2015) 'Cost Estimate Report for Tees Valley Unlimited: Work Package 7, Whole Project Cost Estimating'.

ONS Input-Output tables, which were applied to calculate the indirect effects. Assumptions about the labour intensity of output for each sector were used to estimate the effect on local and UK employment (see Table A.2).

Table A.2: Economic assumptions for capital expenditure

Capital cost component	Economic sector	CAPEX cost (£m)[1]	Labour intensity (jobs/£m output)[2]	GVA multiplier[3]	Employment Multiplier[3]
Civils		**£51.58**			
Demolition	Specialised construction activities	£0.00	9.0	1.89	2.01
Site Prep	Specialised construction activities	£0.59	9.0	1.89	2.01
Buildings	Construction of buildings	£31.41	4.4	1.89	2.01
Civils	Civil engineering	£12.06	5.0	1.89	2.01
Site works	Specialised construction activities	£7.52	9.0	1.89	2.01
Mechanical, Instruments & Electrical		**£374.46**			
Equipment	Manufacture of machinery and equipment n.e.c.	£138.20	5.6	1.70	1.63
Materials & Bulks	Manufacture of basic metals	£205.82	4.1	2.57	2.47
Installation	Repair and installation of machinery and equipment	£8.67	6.8	1.88	1.76
Commissioning	Legal and accounting activities	£17.62	10.3	1.33	2.09
1st Fill Chemicals	Manufacture of chemicals and chemical products	£4.15	3.3	2.24	2.05
Offshore		**£184.50**			
Procurement	Mining support service activities	£134.52	3.5	1.47	3.34
Shore Approach	Mining support service activities	£2.66	3.5	1.47	3.34
Offshore Installation	Civil engineering	£47.32	5.0	1.89	2.01
Capital cost component	**Economic sector**	**CAPEX cost (£m)[1]**	**Labour intensity (jobs/£m output)[2]**	**GVA multiplier[3]**	**Employment Multiplier[3]**

Engineering & Management		**£82.51**			
F.E.E.D.	Architectural and engineering activities	£12.21	7.8	1.72	2.74
Engineering	Architectural and engineering activities	£34.08	7.8	1.72	2.74
Project Management	Activities of head offices; management consultancy activities	£21.30	8.8	1.56	2.14
Construction Management	Activities of head offices; management consultancy activities	£12.78	8.8	1.56	2.14
Surveys & Studies	Scientific research and development	£2.13	7.5	1.80	1.59
Certification & Insurance		**£21.37**			
Certification	Insurance, reinsurance and pension funding	£6.11	1.4	2.18	2.16
C.A.R. Insurance	Insurance, reinsurance and pension funding	£15.27	1.4	2.18	2.16

Sources:
1 AMEC Foster Wheeler/RHi report: Cost Estimate report for Tees Valley Unlimited, March 2015.
2 ONS Annual Business Survey 2013.
3 ONS 2010 Input-Output Analytical Tables

Similarly, the economic effects associated with the operation and maintenance of the CCS network were calculated by applying multipliers to the domestically produced share of output from these sectors (see Table A.3). Historical labour productivity data from the ONS was applied, at a sectoral level of detail, to estimate employment effects.

Table A.3: Economic assumptions for operating expense for existing industries

OPEX Cost Type	Economic sector	OPEX cost (£m)[1]	Labour intensity (jobs/£m output)[2]	GVA multiplier[3]	Employment Multiplier[3]
Fixed					
Direct Labour	Electricity, gas, steam and air conditioning supply	£1.26	-[4]	3.09	2.74
Admin/ overheads	Office administrative, office support and other business support activities	£0.38	7.8	1.49	2.35
Maintenance	Repair and installation of machinery and equipment	£13.87	6.8	1.88	1.76
Insurance	Insurance, reinsurance and pension funding	£17.15	1.4	2.18	2.16
Variable					
Power and steam	Electricity, gas, steam and air conditioning supply	£58.92	1.2	3.09	2.74

Sources:
1 AMEC FOSTER WHEELER report: Cost Estimate report for Tees Valley Unlimited, March 2015.
2 ONS Annual Business Survey 2013.
3 ONS 2010 Input-Output Analytical Tables
4 Direct labour figure based on AMEC Foster Wheeler/RHi report.

The economic contribution of the four plants that have already expressed an interest in joining the CCS network was estimated using current employment and turnover figures from those plants. Multipliers were applied to calculate the extent to which these plants support additional economic activity and jobs in their associated supply chains.

To estimate the effect of new industries that may be attracted to the network, a scenario was formed, in which it is assumed that new plants will join the network until full capacity is reached. The new installations that were assumed to join the network over the period 2025-2035 included: a number of additional chemicals plants that are already located in the Tees Valley; a coal IGCC CCS-equipped power plant; an additional CCS-equipped chemicals plant; an oil processing plant; an additional CCS-equipped chemical plant; a new CCS-equipped cement plant.

For each installation, estimates of the capital cost of constructing and/or connecting the plant to the CCS network were formed, based on the size of the plant (determined by CO_2 emissions); whether the plant was assumed to be new or existing (with retrofit CCS); and AMEC Foster Wheeler/RHi analysis of the proportion of capital costs attributable to each economic sector for the four firms that are initially connected to the network. The geographical characteristics of the supply chains, multipliers and labour market characteristics were applied to estimate the economic effects (in a similar way to that described for the initial investment phase).

The economic contribution of plants that are assumed to connect to the network over the period 2025-2035 was also estimated. For new industries, this estimate was based on similar plants in the UK and for existing Teesside industries, this estimate was based on current employment figures. We made the conservative assumption that existing process plants are already operating at full capacity and that there is no opportunity for them to expand or increase production in the future. This means that estimated labour productivity growth in these industries (which varied, by sector, between 2-5% per annum) led to a reduction in the level of employment, rather than a real increase in economic output. It is therefore likely that this approach underestimates the true economic contribution of these industries, as we do not account for potential improvements in the manufacturing process that could increase the future volume of production from these industries.

In addition, we estimated gross exports from the new firms that may be attracted to the network, based on data from the ONS on the average share of exports in the associated industry sector (see Table A.4). It is important to note that these are estimates of *gross* exports form industries that join the CCS network. It is likely that these industries will import raw materials to the production process and so the effect on *net* exports is expected to be lower.

Table A.4: UK GVA and exports by sector, average over 2008-2012

Sector	Total Supply* (£m)	Exports (£m)	Exports/Total Supply (%)
Coke and petroleum products	96,585	21,947	23%
Other chemicals	9,972	5,079	51%
Industrial gases, inorganics and fertilisers (all inorganic chemicals)	6,402	2,842	44%
Cement, lime, plaster and articles of concrete, cement and plaster	7,621	224	3%

Source: BB2014 Supply and Use Tables
*Total supply includes domestic output and imports

Limitations The principal limitation of this study is that we have only considered the gross effects of developing a CCS network. We have assumed that the CCS network is publically funded and have not modelled any change in taxes, government borrowing, or consumer prices to pay for this investment cost.

We have not taken into account induced effects that could occur as the increase in employment that is brought about by the investment stimulus would lead to higher incomes, a likely increase in consumer expenditure and, as a result of this increase in demand, a further increase in GVA and employment. We have instead only considered the effects in industries that are directly affected by the investment stimulus and those industries in the associated supply chain.

Another key limitations is that the development of the CCS network post-2025 is particularly uncertain and so our analysis of these affects are heavily based on assumptions about the types of industry that will be attracted to the network, and key characteristics of these industries (including emissions intensity and labour productivity). The figures indicating future employment and GVA in industries that may eventually be attracted to the network are for illustrative purposes only.

Finally, whilst we have used the most detailed sectoral data that is publically available, there are still substantial variations in labour productivity and profitability at the firm-level. For this analysis, we have used UK industry averages (at the SIC 4-digit level of detail) to indicate labour productivity, profitability and wage costs in specific sectors. However, in some cases, this level of detail may not be adequate to accurately assess firm or plant level GVA and employment effects.

Appendix B Detailed economic results

Table B.1: GVA impacts (by sector) of the CAPEX investment in first phase of CCS network (constructed over 2021-2025) (£m)

	2021	2022	2023	2024	2025
Tees Valley Region					
Construction	0	2	5	5	0
Mechanical, Instruments & Electrical	2	2	5	3	3
Offshore Pipework	9	13	13	13	0
Engineering & Management	8	8	2	2	2
Certification & Insurance	0	0	3	3	0
UK					
Construction	1	2	8	8	0
Mechanical, Instruments & Electrical	7	7	12	4	4
Offshore Pipework	15	20	21	21	0
Engineering & Management	9	10	2	2	2
Certification & Insurance	0	0	5	5	0
Indirect	22	29	36	27	3

Table B.2: Employment impacts (by sector) of the CAPEX investment in first phase of CCS network (constructed over 2021-2025) (jobs)

	2021	2022	2023	2024	2025
Tees Valley Region					
Construction	10	26	64	64	0
Mechanical, Instruments & Electrical	27	27	66	37	36
Offshore Pipework	71	119	122	122	0
Engineering & Management	117	123	33	33	33
Certification & Insurance	0	0	9	9	0
UK					
Construction	16	40	101	101	0
Mechanical, Instruments & Electrical	108	108	178	59	57
Offshore Pipework	113	188	193	193	0
Engineering & Management	140	147	39	39	39
Certification & Insurance	0	0	14	14	0
Indirect CAPEX	614	729	702	579	108

Table B.3: UK employment impacts resulting from construction and operation of 15MtCO_2pa CCS network and inward investment from new CCS plants

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
CAPEX jobs	376	483	525	406	257	176	1414	1399	2261	1838	1285	574	562	375	100
OPEX jobs	0	0	0	0	139	139	139	139	162	162	167	167	172	172	177
Indirect jobs	614	729	702	579	525	437	2,016	2,076	2,677	2,284	1,783	1,009	930	751	529

Table B.4: Direct jobs in the Tees Valley that could be supported by existing and new industries joining the CCS network

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Existing industries in 2025	2,702	2,667	2,633	2,600	2,568	2,537	2,507	2,477	2,449	2,421	2,394	2,368	2,342	2,317	2,292
New industries post-2025	0	0	0	0	0	0	0	0	1,490	1,565	1,957	1,957	2,026	2,300	2,450
CAPEX related jobs	225	294	294	264	160	102	898	910	1,317	1,193	818	360	325	246	72
OPEX related jobs	0	0	0	0	139	139	139	139	162	162	167	167	172	172	177

Note: 'CAPEX-related jobs' includes jobs supported when the CCS network is constructed in the first investment phase, as well as jobs relating to the construction of new CCS-equipped plants that are assumed to be attracted to the area over 2025-2035, and the CCS retrofitting of some existing industries in the Tees Valley.