A UK Vision for Carbon Capture and Storage

FINAL REPORT

Prepared for:

The Trades Union Congress and
Carbon Capture and Storage Association

Prepared by:

Orion Innovations (UK) Ltd.

Date: November 2013

Orion Innovations (UK) Ltd. 1 Quality Court Chancery Lane London WC2A 1HR

Tel: +44 203 176 2721 Email: info@orioninnovations.co.uk

CONTENTS

GLOSSARY

CCC	Climate Change Committee
CCGT	Combined cycle gas turbine
CCTG	Clean Coal Task Group
CCSA	Carbon Capture and Storage Association
CCTF	Cost reduction task force
CHP	Combined heat and power
CNS	Central North Sea
EII	Energy Intensive Industries
EIUG	Energy Intensive Users Group
EMR	Electricity Market Reform
EOR	Enhanced oil recovery
ETI	Energy Technologies Institute
EU ETS	EU Emissions Trading System
FEED	Front End Engineering Design
FID	Final investment decision
FiT CfD	Feed in Tariff Contracts for Difference
FOAK	First of a kind
FTE	Full time equivalent
GDP	Gross domestic product
GVA	Gross value added, the value of goods and services produced in an area, industry or sector of an economy
LCF	Levy Control Framework, a Treasury cap on how much money can be levied on consumers' energy bills
MtCO2e	Mega tonnes (million tonnes) of CO2 equivalent
NOAK	Nth of a kind
IEA	International Energy Agency
IGCC	Integrated Gasification Combined Cycle – also known as pre-combustion CCS
O&M	Operations and maintenance
PC	Pulverized coal-fired boiler
TUC	Trades Union Congress

1 Executive summary

The UK's carbon capture & storage industry is at a crossroads. Urgent Government action is needed to ensure that this new technology-based industry develops in a timely manner, delivering significant economic growth and employment benefits and contributing towards the UK's carbon reduction targets.

Delivering the optimum UK energy mix over the next 20 years involves multiple challenges:

- A significant rise in demand for electricity, driven by economic growth and greater use of electricity at home and in industry and transport.
- Replacing a fifth of older power plant by 2020.
- Delivering legally binding CO2 emissions reductions of 60% by 2030, with the near-complete decarbonisation of electricity supply sector, and significant reductions in industry.

A balanced and effective energy strategy will be critical to ensuring that electricity and heat remain **on tap and affordable** to both industry and domestic consumers alike.

Through a series of energy market reforms the government's Energy Bill is tasked with delivering the framework for £110bn of secure, low carbon and affordable energy investment by 2020. **Investing in 'green growth'** within the UK economy will provide jobs, tax revenues, inward investment and export potential.

Carbon capture & storage (CCS) technology can deliver on all these counts - providing least cost, secure energy in association with green growth:

- **Lower energy costs:** including CCS within the future decarbonised energy portfolio is **consistent with the least cost pathway to decarbonisation**. Analysis commissioned by the Energy Technology Institute shows CCS can deliver a 15% reduction in the wholesale price of electricity – an £82 reduction in household electricity bills per year (by 2030) – compared to a scenario without CCS. This is crucial, not only for householders, but for maintaining energy intensive manufacturing in the UK. This in turn will safeguard the value of goods and services produced in our regions, and many thousands of jobs.

  A recent study by the CCS *Cost Reduction Task Force* has provided strong evidence that CCS can become cost competitive with other low-carbon technologies. '*UK gas and coal power stations equipped with carbon capture, transport and storage have clear potential to be cost competitive with other forms of low-carbon power generation, delivering electricity at a levelised cost approaching £100/MWh by the early 2020s, and at a cost significantly below £100/MWh soon thereafter*.'
- **Energy security**. CCS technology is currently the only way fossil fuels can be sustained within the UK generation mix. Enabling clean energy production from coal and gas power will address energy security concerns, support the exploitation of valuable indigenous resources (coal and gas), and reduce future reliance on imported fuel. This will be enhanced if the UK coal mining industry is sustained through the transition period, until coal-based CCS is widely implemented.
- **Lower capital expenditure**. CCS enables continued use of existing energy production, transport and generation infrastructure, and therefore delays retirement of valuable assets, avoiding increases in production costs.
- **Energy reliability**. CCS would be a particularly effective player within a mixed energy portfolio that includes increasing quantities of wind and nuclear power, providing a readily dispatchable back-up load to mitigate against the intermittent nature of wind power and inflexibility of nuclear.
- **Industrial CCS** offers the only option for CO2 reduction of some key heavy industry process emissions, and is therefore the only means by which the energy intensive industries such as steel, cement and chemicals can continue to operate in a carbon-constrained world. CCS will thus play a significant role in safeguarding the 160,000 direct employees, 800,000 indirect employees, and combined GVA of over £14bn contained within these industries.

- **Jobs and green growth**. The CCS sector represents a major growth opportunity for the UK, not only in the long term, but also in the immediate future: between 5 and 7 power and industry 'shovel ready projects' (i.e. projects that could begin operating before 2020) are in a position to kick start this green growth within the next parliamentary term, 2015-2020. With the right support, the UK could install 20 GW CCS by 2030, or between 15 and 25 projects.
- Each project in the power sector could deliver £150 million a year in gross value added (GVA) benefits associated with construction (over a six year period), and £200 million a year from 2020 in operation (based on calculations for first of a kind (FOAK) plant).
- Early deployment will establish the UK as a globally leading player within the sector, ensuring that UK-based companies capture a significant share of the domestic (75% or more) and global markets (up to 10%).
- **CCS will create a significant number of jobs:** an average CCS power plant generates up to 2500 jobs during the construction period, and 200–300 longer term jobs in operation and maintenance (new-build only). A conservative project-based assessment gives an estimate of total annual employment of 30,000 by 2030 with 20 GW installed capacity.
- **Global markets** will offer substantial export opportunities. It has been calculated that 964 GW of total installed CCS power generation capacity will be needed globally by 2050 to reach required emissions reductions,[1] creating a market worth over £100bn per year from 2020, in particular in the US, China, India and other coal and gas dependent nations.

The UK has a unique combination of physical and human assets to develop CCS, providing the opportunity to become a global lead player in the CCS sector:

- Abundant North Sea offshore CO2 storage sites in depleted oil and gas fields and deep saline formations. The Energy Technologies Institute (ETI) estimates that the sub-seabed of the North Sea can store 80 billion tonnes of CO2 – more than enough to meet the needs of UK CCS. The UK storage potential is so large that there may even be opportunities to offer storage facilities and services to neighbouring EU countries.
- Existing oil and gas pipelines and offshore platforms that have the potential to be re-commissioned for CCS.
- World class skills in related engineering fields, primarily resulting from long-standing experience in the oil and gas, energy supply and process industries. These include power plant and process engineering; design, build, and commissioning of major infrastructure projects; construction and operation of pipelines; sub-surface analysis; and CO2 storage, including reservoir operations and field services.
- Strong capability in ancillary services associated with CCS such as planning, environmental impact assessment, managing public perceptions, verification, financing, and insurance and legal services.
- Well established R&D in CCS at leading research centres and in the private sector.

The UK thus has the skills, infrastructure and physical resources to develop a world-class domestic industry that can form the basis for meeting the anticipated high growth in the global CCS markets.

Government support initiatives for CCS

DECC has laid out its intended means to support CCS in the 2012 Roadmap.[2] Despite these measures, there are significant gaps in the government's support framework that will hinder the successful development of the sector.

DECC's principal aims are to reduce costs, create an effective market framework and address the key barriers to implementation. Two initiatives are of particular relevance:

- **A CCS commercialisation programme** based around £1bn competitive funding for "up to four" commercial scale CCS projects. This aims to reduce future project risk by demonstrating commercial viability and the regulatory framework.

[1] IEA 2 Degrees emissions reduction trajectory.
[2] DECC CCS Roadmap, Supporting deployment of Carbon Capture and Storage in the UK, April 2012.

- **Developing a market for low-carbon electricity** that will allow CCS to compete with other low-carbon technologies, primarily via new Feed-in Tariffs linked to new Contracts for Difference for CCS within the government's Electricity Market Reform.

DECC, in collaboration with The Crown Estate and the CCSA, also established the *CCS Cost Reduction Task Force* to investigate the activities needed to make CCS cost competitive with other low-carbon technologies in the 2020s. Their final report demonstrates clear belief that sufficient cost reduction is achievable in the 2020s provided that critical actions are taken by Government and industry stakeholders. Of particular importance are:

- Development and optimisation of a CCS transport network and associated storage.
- Public support for early commercial projects, including measures to reduce risk and improve investor confidence.
- Exploitation of the potential for use of CO2 in the North Sea for additional oil recovery.

Additional government action is needed *urgently* to ensure the long term future of a thriving UK CCS sector

Despite these Government initiatives, there are significant policy gaps that will hinder the successful development of the sector. Urgent action is needed to fill these gaps and ensure that the CCS industry develops in a timely manner, delivering significant economic benefits and contributing towards the realisation of carbon reduction targets:

1. A strongly endorsed long-term Government vision for the CCS sector.
2. Immediate and steady rollout of CCS projects: including a minimum of 2 projects from the current CCS competition, ready to begin operating from 2018; and positive final investment decisions for shovel ready projects outside the competition within the next parliament.
3. Successful implementation of the Government's Electricity Market Reform, particularly through the development of low-carbon support mechanisms, such as the Feed in Tariff with Contracts for Difference, that catalyse CCS investment.
4. Development of CO2 transport and storage infrastructure that can service the needs of not just current emitters, but also future power and industrial facilities.
5. The development of support mechanisms for CCS in industrial applications.

CCS at a crossroads

Failure to deliver CCS as a key mechanism for cutting our carbon emissions will have profound implications for the UK economy. Estimates show that without CCS, the cost of a low-carbon energy mix in 2050 would increase by 1% of GDP or £30-40 billion per year.

Delivering carbon emissions reductions at the levels required from the UK, Europe and globally without carbon capture technology results in a significant increase in costs, which will in turn impact directly on consumer bills (domestic and industrial). Delaying deployment of CCS until the 2020s or 2030, and then attempting to deploy at a faster rate, is likely to push up costs as the supply chain becomes overstretched.

Fossil fuels currently provide robust, flexible and diverse sources of electricity. Without CCS their limited future role in the energy system will impact negatively on the security and diversity of electricity supply.

For key industries, CCS is the only technology which will enable significant emissions reductions. If CCS is not available, then ultimately many of those industries may have to relocate out of the UK, with major loss of employment and revenue.

The UK is fortunate to have a range of well designed, "shovel ready" CCS projects with great potential, ready to go forward over the lifetime of the next parliament. They would stimulate short-term growth in jobs, skills and regional economies, whilst laying the building blocks for realising the longer-term socio-economic benefits of this key technology for power and industry. CCS is at a crossroads. We must act now to realise this potential.

Acknowledgements

This study was jointly commissioned by the Carbon Capture and Storage Association (CCSA) and the TUC. We would like to express our appreciation for the support of the CCSA industrial members, trade union and industry members of the TUC's Clean Coal Task Group (CCTG) in drafting this study, and in particular the CCTG chair, Mike Gibbons OBE and Chris McGlen. We would also like to acknowledge the ETI, whose recent research on CCS has made a significant contribution to this study.

2 Brief overview of CCS technology

Carbon capture and storage incorporates a suite of technologies that enable the isolation of CO2 from hydrocarbon fuel and industrial manufacturing process waste streams; followed by compression, transport, and injection into permanent geological storage. The technology can be used in association with electricity generation (coal, gas and biomass) and a number of energy intensive industry sectors, including manufacture of cement, iron and steel, chemicals, refineries and natural gas processors.

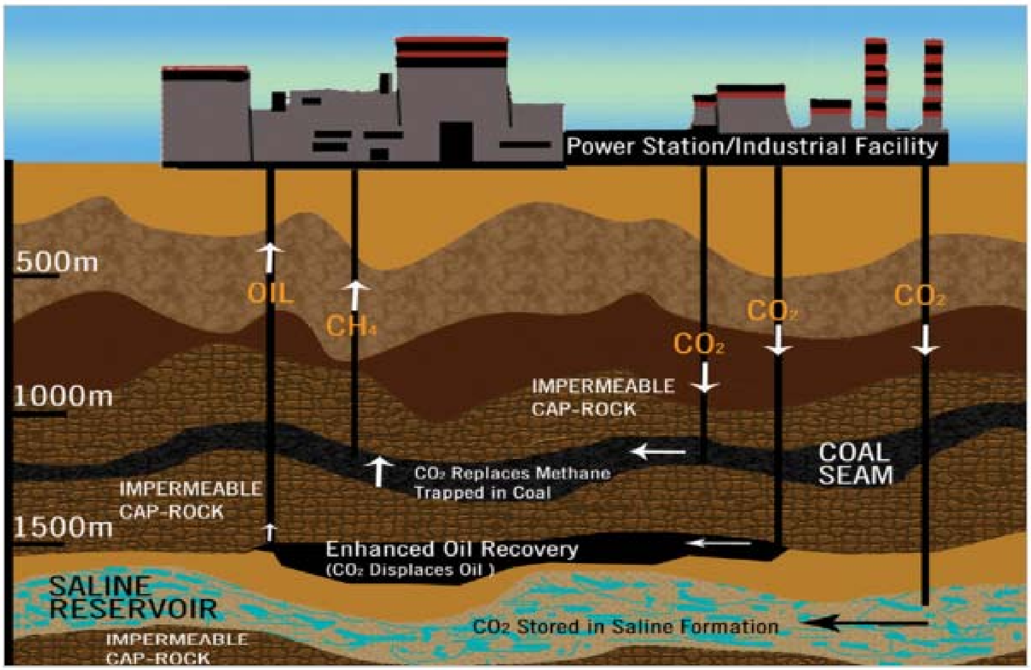
The capture process may take one of three forms:

- Pre-combustion involves converting solid, liquid or gaseous fuel into a mixture of hydrogen and carbon dioxide via gasification or reforming. The remaining hydrogen rich fuel can be burnt in modified turbines to produce electricity or is available for use in industrial processes or potentially transport applications. Pre-combustion coal is also known as Integrated Gasification Combined Cycle (IGCC) with CCS.
- Post-combustion involves separation of CO2 from flue gas using a range of processes including membranes, cryogenic distillation and absorption. Due to the low concentration of CO2 in the post combustion gas, this requires large scale equipment, able to process large quantities of gas.
- Oxy-fuel combustion involves burning hydrocarbon and/or biomass fuels in oxygen-rich environment rather than simply air, resulting in a flue gas containing high concentrations of CO2 and water.

All parts of the process are capital intensive and require additional energy input. The increase in consumption of fuel resources for electricity generation with CCS in order to produce the same amount of electrical energy has been estimated at 17-30% depending on type of plant.[3]

All three capture technologies are well developed and ready to be deployed at a commercial scale in the power sector. Within the industrial sector, some processes (e.g. in natural gas processing and ammonia production), already involve capture and separation of CO2, and transport and storage represent the only challenge to implementing CCS. Other industrial sectors, e.g. cement, iron and steel manufacture, may need further development and demonstration of capture technologies at pilot scale before commercial scale deployment is feasible.

Figure 1. Carbon Capture and Storage Flow Chart, World Resources Institute[4]



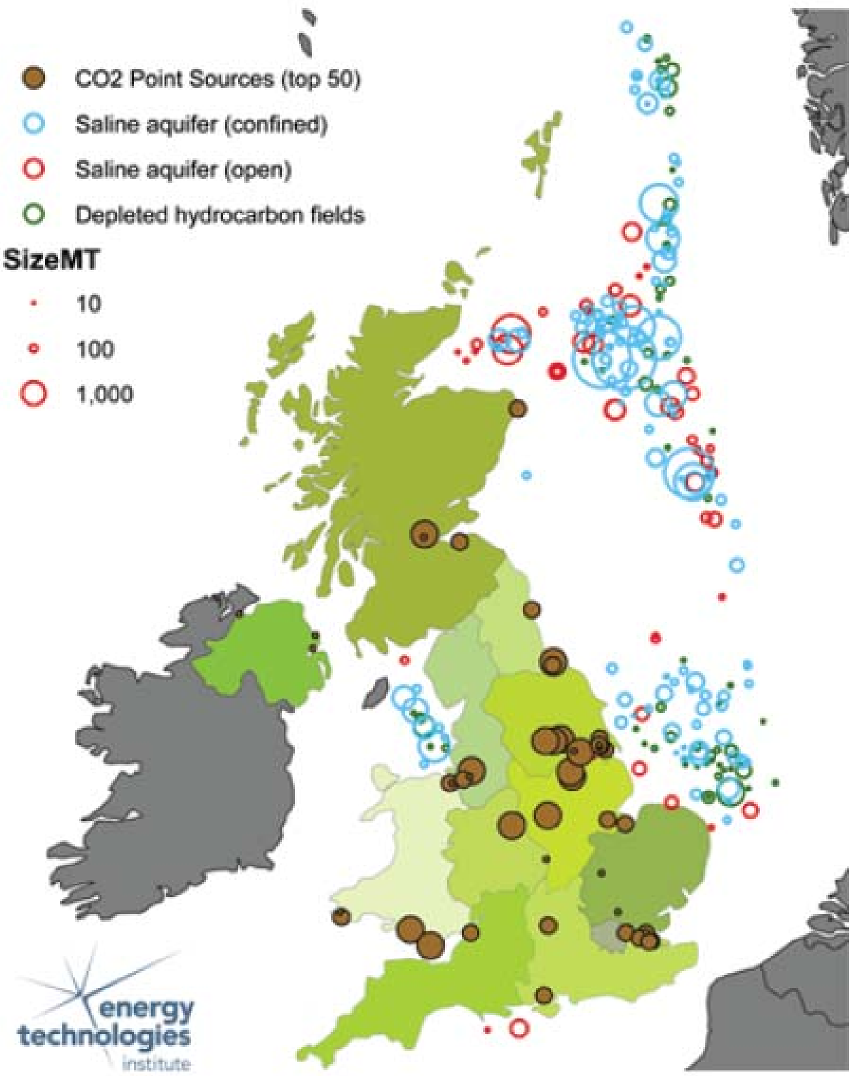
[3] IEA, Energy technology Perspectives, 2012.
[4] http://www.wri.org/resources/charts-graphs/carbon-capture-sequestration-flow-chart.

Capture is followed by transport and storage:

- Compressed CO2 is transported via pipeline or ship, essentially in the same manner as natural gas, oil and many other fluids are moved around the world. Reuse of redundant pipelines is a cost-effective option.
- Storage sites are available in the North Sea and East Irish Sea in deep (at least 1 km below the earth's surface) porous geological formations under sufficient pressure to maintain the CO2 in the liquid phase. Suitable storage sites include former gas and oil fields, deep saline formations, or depleting oil fields where the injected carbon dioxide may increase the amount of oil recovered (Figures 1 and 2).

These technologies are also well understood and have been used in the oil and gas industry for many years.

Figure 2. Proximity of the UK's largest industrial emitters to CO2 storage sites in the North and Irish Seas[5]



[5] Map sourced from DECC CCS Roadmap 2012 and provided by the Energy Technologies Institute.

3 The policy context

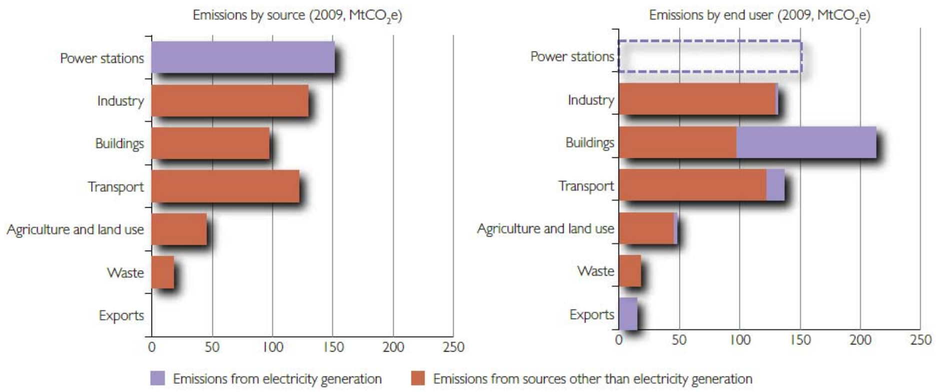
Highly ambitious but essential CO2 emissions reduction targets form a key part of the framework for the UK's energy and climate policy to 2030 and beyond. The 2008 Climate Change Act established the world's first legally binding climate change target to reduce the UK's greenhouse gas emissions by at least 80% (from the 1990 baseline) by 2050.

The UK currently emits approximately 580 MtCO2e per year, of which over 80% is accounted for by CO2.[6] The majority of carbon emissions are accounted for by three major end users:

- Buildings (38%): burning fossil fuels to heat buildings and workplaces, and generating the electricity that powers lighting and appliances.
- Transport (24%): direct use of fossil fuels in land transport, shipping and aviation.
- Industry (25%): heat production and process industry specific chemical reactions.

In terms of emissions by source, the power sector is the largest emitter (27%). As heating, transport and industry become increasingly electrified, electricity demand is anticipated to rise by 30% to 60%, by 2050.

Figure 3 Emissions by source and end user[7]



Source: DECC National Statistics
Note: The 'exports' category relates to emissions within the UK from producing fuels (e.g. from a refinery or coal mine) which are subsequently exported for use outside the UK.

In the 2011 Carbon Plan, the Government set out a vision for achieving the 80% emissions reduction target:

- The electricity sector should be substantially decarbonised by 2030 and be almost completely carbon free by 2050.
- 70% carbon emissions reductions in industry from 2009 levels by 2050.
- Average new car emissions need to be 50–70 gCO2/km and new van emissions 75–105 gCO2/km by 2030. Much of this will need to come from the electrification of transport.

The Government's current Energy Bill, with its reforms to the electricity market, is at the heart of achieving the decarbonisation of electricity supply **at a cost that is affordable for consumers**, whilst ensuring that supply can meet demand at all times. There are four primary elements:

- Carbon Price Support – guarantees a minimum price for carbon (via the Climate Change Levy and fuel duty) on all fossil fuels used to generate electricity, based on carbon content. The tax has been in place since April 2013, with a floor price of £16/tCO2 and will be increased on an annual basis in order to hit the target price of £70/ tCO2 in 2030 (in 2009 money).
- Feed-in Tariffs with Contracts for Difference (FiT CfDs) – designed to stimulate investment in low-carbon projects. The tariffs provide an agreed price for low-carbon generation over the lifetime of the plant. Power stations fitted with carbon capture and storage will be eligible for support and this will a key mechanism underpinning investment in CCS technologies.

[6] DECC, UK GREENHOUSE GAS EMISSIONS – QUARTERLY STATISTICS: 1st QUARTER 2013 PROVISIONAL FIGURES, July 2013.
[7] DECC The Carbon Plan: Delivering our low carbon future, December 2011.

- Capacity Market – auctions to secure reliable supply (or demand reduction) of one year duration up to four years in advance. These are due to start in 2014 to secure capacity in 2018. The capacity market is technology neutral. However, installations that receive CfDs will not be eligible to participate in the capacity market.
- Emissions Performance Standard – limits emissions from new fossil fuel power stations from Autumn 2013 (level set at 450g CO2/kWh), effectively mandating CCS with any new coal-fired power stations. New gas-fired power stations that are consented under the current level can remain at this level until 2045 (a term known as 'grandfathering').

The UK's policy framework for CCS is set out in the CCS Roadmap, published in April 2012. Aside from CfDs for CCS, the other main development announced in the Roadmap was the CCS commercialisation programme (competition), which is currently underway. Two preferred bidders have been selected in this competition, and more details are expected to be announced before the end of 2013 (see Section 6 for more information).

More than 70% of energy used in industry is for heat generation. In 2012, DECC published a strategic framework for the provision of affordable, secure and low-carbon heating, which addresses the need to decarbonise heat production in both buildings and industry. This was followed by an implementation plan in 2013.[8] The Government acknowledges the future importance of CCS in achieving further emissions reductions from industrial sectors, such as steel, cement, ammonia, chemicals and refining, (a number of which generate CO2 not only as a by-product of heat generation but also as part of their production processes). However, it is yet to propose specific support policies for industry CCS. The Government has also recognised the challenge of reducing carbon emissions from the Energy Intensive Industries (EIIs) without jeopardizing their international competitiveness (see Section 5.4). To this end, DECC and BIS have initiated development of a decarbonisation 'roadmap' for each of the industrial sectors, focusing on those that use the greatest amount of heat and represent the greatest CO2 emissions. This will offer the opportunity to analyse and embed the opportunities for CCS to contribute to decarbonisation within different sectors. It will be essential to align these plans with those developed as part of Government's wider efforts on CCS.

Set against the need to reduce carbon emissions at lowest cost, is the need to provide secure electricity supplies in the face of ever increasing demand. 35 GW of existing fossil-fuel and nuclear based generation is due to close over the next 10 years, not only as a result of reaching plant 'end of life', but also through voluntary rejection of emissions regulations imposed by the European Large Combustion Plant Directive and follow on Industrial Emissions Directive. At the same time, recent analysis by Ofgem has indicated that demand for electricity could rise to the point where power cuts are increasingly likely. So-called "capacity margins" could tighten considerably faster than previously anticipated towards 2015, before the EMR's Capacity Market starts to deliver. This means that the probability of a supply disruption could increase from 1 in 47 years now to around 1 in 12 years (or less) for 2015/16.[9]

Considerable challenges are thus posed by the fundamental requirement for secure, cost effective and low-carbon energy. On the other hand, the Government has acknowledged that the same challenges offer significant opportunities for 'green growth' within the UK economy, providing jobs, tax revenue, inward investment and export potential.

> Ed Davey 'I have long believed in the need to marry our economic and environmental agendas. Greening the economy isn't just good for the planet - it's good for the wallets, purses and pockets of every British citizen too.'[10]

'Enabling the transition to a green economy' (August 2011) the associated 'Skills for a green economy' (October 2011), published by BIS, DECC and Defra, set out the opportunities for a Green Economy, together with the skills development needed to realise those opportunities.

[8] DECC, The Future of Heating: A strategic framework for low carbon heat in the UK, March 2012; The Future of Heating: Meeting the challenge, March 2013.
[9] Ofgem Press Release, OFGEM REPORT HIGHLIGHTS THE IMPORTANCE OF GOVERNMENT REFORMS TO ENCOURAGE MORE INVESTMENT IN GENERATION, June 2013.
[10] https://www.gov.uk/government/news/going-for-growth-means-going-for-green.

4 Current consensus: the advantages of CCS in the future energy mix

There is considerable agreement amongst climate change institutions (including the IEA, CCC and ETI) on the crucial role that CCS will play in **cost effectively** realising emissions reduction targets. For example, the IEA's Energy Technology Perspectives 2 Degrees Scenario (2DS), a least cost modelling scenario,[11] showed that CCS is a critical part of the future energy portfolio, contributing 17% to global emissions reduction in 2050 and 14% of the cumulative emissions reductions between 2015 and 2050.

Within the UK, CCS will provide additional benefits:

- **Energy security**. CCS technology is currently the only means by which fossil fuels can be maintained within the UK generation mix. Enabling clean energy production from fossil fuels will address energy security concerns, supporting the exploitation of valuable indigenous resources (coal and gas), and reducing future reliance on imported fuel. This will be enhanced if the UK coal mining industry is sustained through the transition period, until coal-based CCS is widely implemented.
- **Energy reliability**. Coal and gas fired power stations with CCS provide a dispatchable electricity source to complement the intermittency of renewables and the inflexibility of nuclear power.
- **Lower capital expenditure**. CCS enables continued use of existing energy production, transportation and generation infrastructure (and therefore delays retirement of valuable assets), which avoids increases in production costs.
- **Industrial CCS** offers the only option for CO2 reduction of industry process emissions.

There is also agreement that the UK has the **opportunity to become a leading player** in the CCS sector, with:

- Close proximity to abundant offshore CO2 storage sites in both depleted oil and gas fields and deep saline formations in the North Sea. The Energy Technologies Institute (ETI) estimates that the sub-seabed of the UK section of the North Sea can store almost 80 billion tonnes of CO2 – more than enough to meet the needs of UK CCS projects for the next 100 years. The UK storage potential is so large that there may even be opportunities to offer storage facilities and services to neighbouring EU countries.
- Existing oil and gas pipeline assets and offshore platforms that have the potential to be re-commissioned for CCS.
- World class skills in related engineering fields, primarily resulting from long-standing experience in the oil and gas, energy supply and process industries. These include power plant and process engineering, design, build, commissioning of major infrastructure projects, construction and operation of pipelines, sub-surface analysis, and CO2 storage, including reservoir operations and field services.
- Strong capability in ancillary services associated with CCS such as planning, environmental impact assessment, managing public perceptions, verification, financing, and insurance and legal services.
- Well established R&D in CCS at leading research centres and in the private sector.

The DECC 2012 CCS Roadmap confirms that the UK Government is committed to supporting the development of a robust CCS sector, provided that technology can be shown to be cost competitive with other low-carbon technologies.

To this end, DECC established the CCS Cost Reduction Task Force in March 2012 to identify opportunities for cost reduction across the CCS value chain. Their recent findings provide a credible pathway, supported by a robust evidence base, for achieving the necessary cost reductions.[12]

---

[11] 80% chance of limiting average global temperature increase to 2°C, IEA Technology Roadmap, CCS, 2013.
[12] CCS Cost Reduction Taskforce, The Potential For Reducing The Costs of CCS in The UK, Final Report, May 2013.

'UK gas and coal power stations equipped with carbon capture, transport and storage have clear potential to be cost competitive with other forms of low-carbon power generation, delivering electricity at a levelised cost approaching £100/MWh by the early 2020s, and at a cost significantly below £100/MWh soon thereafter.'

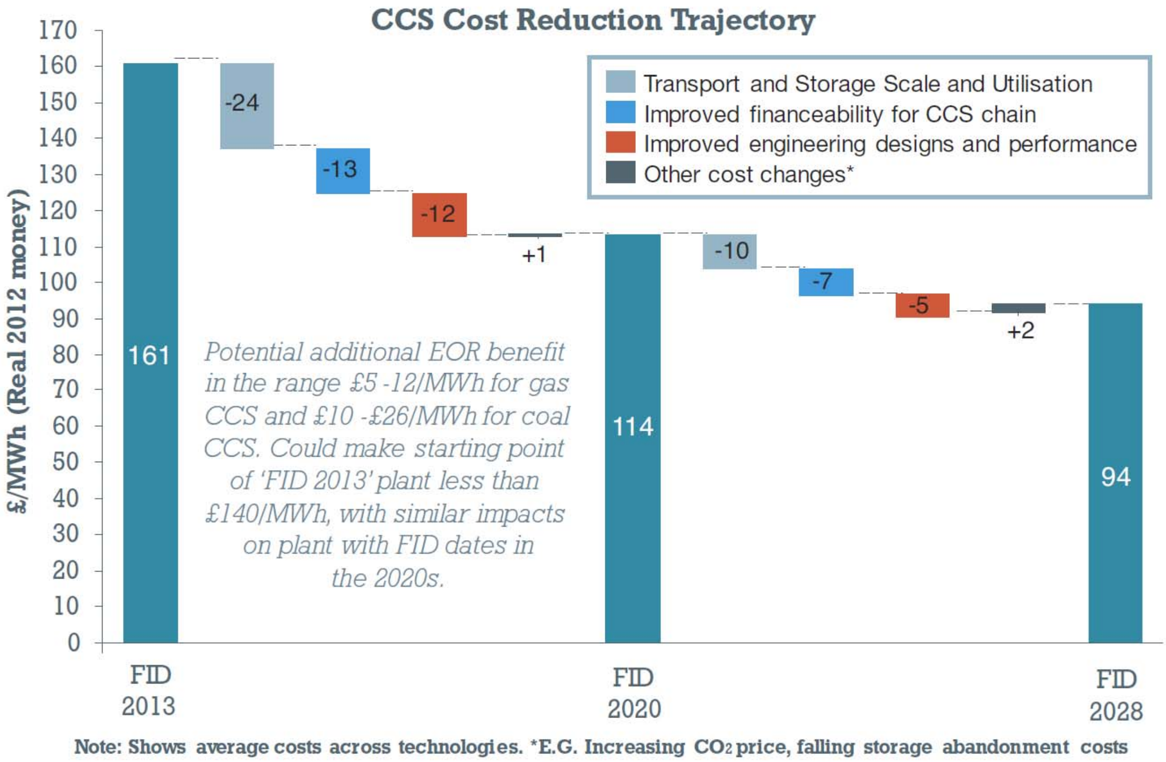


Figure 4. CCTF CCS Cost Reduction Trajectory

Cost reductions are realised through a mix of economies of scale, technology improvements and financial terms, but absolutely key is:

- Public support for early commercial projects as the first of a kind (FOAK), including measures to reduce risk and improve investor confidence.
- A strategic approach to the development and optimisation of a CCS transport network and associated storage hubs.
- Exploitation of the potential for use of CO2 in the North Sea for enhanced oil recovery (EOR).

5 Jobs and consumer benefits

A growing body of evidence is providing greater insights into the socio-economic, as well as decarbonising, merits of implementing CCS.

5.1 Key messages

Analysis commissioned by the ETI shows that inclusion of CCS in the 2030 energy portfolio could result in 15% lower wholesale electricity prices than alternative scenarios in which CCS is not deployed. This in turn will:

- Reduce the level of subsidies (and therefore taxes) needed to decarbonise the electricity sector.
- Increase the disposable income of householders and reduce the risk of fuel poverty.
- Help to maintain presence of energy intensive industries (EIIs) within the UK, with the associated positive impact on the 160,000 direct employees, 800,000 indirect employees, and combined GVA of over £14bn, associated with these industries.

Deployment of CCS is associated with significant jobs and skills benefits, in particular during the construction phase, but also longer term:[13]

- CCS will create a significant number of jobs, with an average CCS power plant installation generating up to 2500 jobs during the construction period, and 200–300 longer term jobs in operation and maintenance (new-build only). A conservative project-based assessment gives an estimate of total annual employment of 30,000 by 2030 with 20 GW installed capacity.
- 5-7 power and industry 'shovel ready projects' (projects that could begin operating before 2020) are in a position to kick start this green growth within the next Parliamentary term (2015 – 2020).
- Each project in the power sector could deliver approximately £150 million a year GVA associated with construction (over a six year period), and £200 million a year from 2020 in operation (based on calculations for first of a kind (FOAK) plants). Total GVA has been estimated at > £5bn a year by 2030 (including export).
- Early deployment is essential to establish the UK as a leading player within the sector, ensuring that UK-based companies capture a significant share of the domestic (75% or more) and global markets (up to 10%).

Power CCS is crucial in:

- Prolonging the life of valuable existing power generation assets.
- Improving energy security through enabling UK fossil-fuel resources to be used in clean power generation (gas and coal).
- Maintaining a highly skilled, domestic coal production industry into the second half of the century.

Industry CCS is also a vital component of the development of the sector:

- To enable industry to cost-effectively decarbonise and thereby ensure the continued existence of the UK's industrial base in a carbon constrained world. CCS is the **only** technology available for sectors in which CO2 is process as well as fuel generated.
- To exploit low cost options for CO2 reduction (where capture is already an intrinsic part of process).
- Together with the power industry, to improve the economic viability of CCS via the formation of clusters, centred around shared transport networks and storage hubs.

Use of CO2 for enhanced oil recovery has the potential to extend the life of the indigenous oil and gas, and associated offshore service, industries whilst improving the economics of the CCS value chain.

Lastly, pre-combustion CCS is potentially a vital tool in the production of cheap, clean hydrogen.

[13] Figures based on multiple analyses. For details see Section 5.3.

5.2 CCS is associated with lower energy costs and consumer bills by 2030

Developing CCS technology is the least cost route to cutting our carbon emissions. The results of carbon reduction models forecasting out to 2030 and 2050 have repeatedly shown that CCS is included in the most cost-effective scenarios, primarily as a result of the higher capital investment needed to reach equivalent carbon reduction with alternative technologies:[14]

- The IEA 2013 CCS Roadmap: without CCS, the cost of limiting global temperature increase to 2 degrees C by 2050 would be 40% higher.
- Energy Technologies Institute ESME model: without CCS, the cost of a low-carbon energy mix in 2050 would increase by 1% of GDP or £30-40 billion per year.

This evidence suggests that a UK portfolio of low-carbon technologies that incorporates CCS would result in the Levy Control Framework (a Treasury cap on how much money can be levied on consumers' energy bills), and by implication the cost to consumers, being set at a lower level than a portfolio without CCS, in order to achieve equivalent decarbonisation of the electricity sector.

New analysis commissioned by the ETI (see below) shows that this translates into a **15% reduction in the wholesale price of electricity**, and **therefore lower industrial, commercial and household energy bills by 2030**.

CCS in the energy mix results in lower electricity prices

MDM-E3 is an econometric input-output model of the UK economy, energy system and environment, maintained and developed by Cambridge Econometrics. It is frequently applied to assess the macroeconomic impact of energy policies and technologies, as well as other energy-environment-economy (E3) interactions. ETI commissioned Cambridge Econometrics to analyse the macro economic impact of developing a CCS sector in the UK. Results from the ETI's optimising ESME[15] model were used as an input to this model of the UK economy. Four scenarios were modelled as alternative means of meeting the 80% carbon emissions reduction target by 2050:

- No CCS: high growth in offshore wind and geothermal which account for 13% and 10% of total electricity generation respectively.
- Power CCS: 15 GW of gas CCS installed between 2020 and 2030. No investment in industry CCS, and relatively small increase in offshore wind capacity.
- Full CCS: investment in both gas and industry CCS, but no coal CCS.
- Full CCS with coal: investment in both power and industry CCS, but with the power sector split between 6 GW of coal and 6 GW of gas by 2030.

Wholesale electricity prices were shown to be significantly less in all CCS scenarios than in the No CCS scenario by 2030, with a 15% reduction in the two optimal scenarios (Power CCS and Full CCS), see Figure 5. Household bills were estimated to be £82 lower per year, by 2030, in the optimal CCS scenario, compared with the baseline, which would have a positive effect on disposable income and consumption. The divergence in cost could begin as early as 2023, but this will not be realised unless the pace of CCS rollout is increased.

To a large extent, the differences in electricity price can be accounted for by differences in the increase in annual capital investment in relation to historical investment. In all three CCS deployment scenarios, power sector investment[16] increases from approximately £5.6bn/yr (1990-2010) to £10bn per year, significantly less than the increase in the No CCS scenario to nearly £13bn/yr (primarily due to the large investment requirements for offshore wind), see Figure 6.

---

[14] CCSA Briefing Paper, Benefits of Carbon Capture & Storage (CCS), March 2013.

[15] The ETI's ESME model is a complete energy system optimizing model that encompasses the inter-linkages between energy supply, energy demand and supporting infrastructure, and can be used to determine the lowest whole energy system cost under different scenarios. In this research it was used with various assumptions for CCS deployment.

[16] Total investment by Electricity, Gas and Water (Utilities) supply sectors

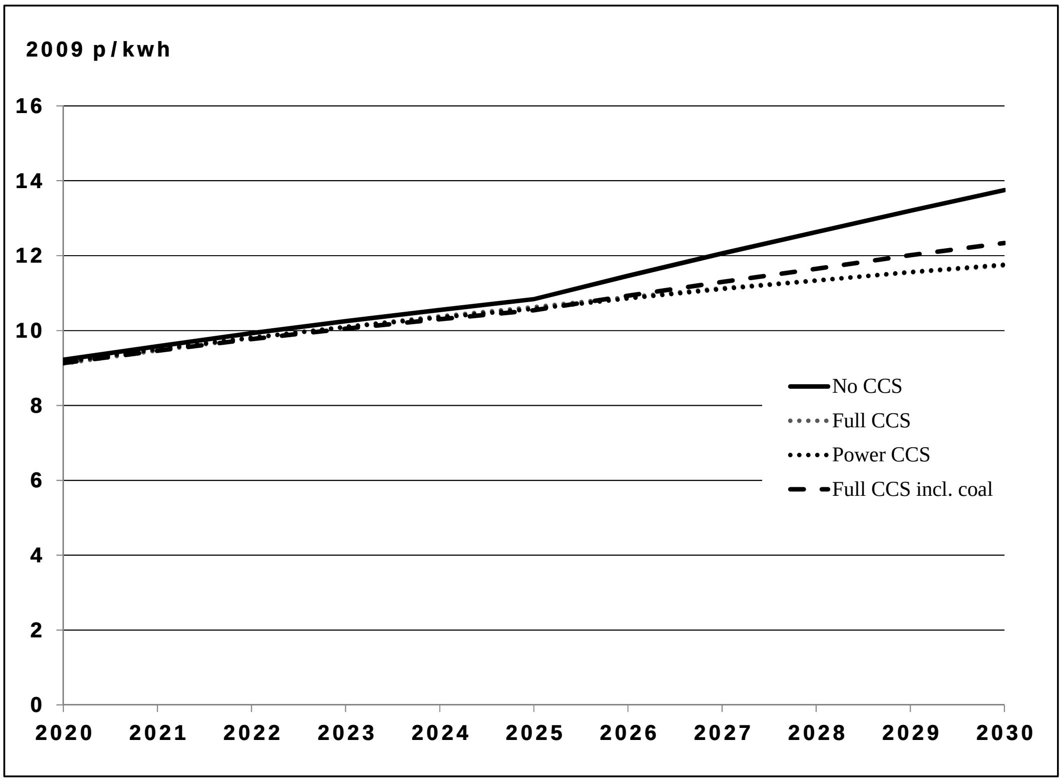


Figure 5. Wholesale Electricity Prices to 2030 under the four scenarios[17]

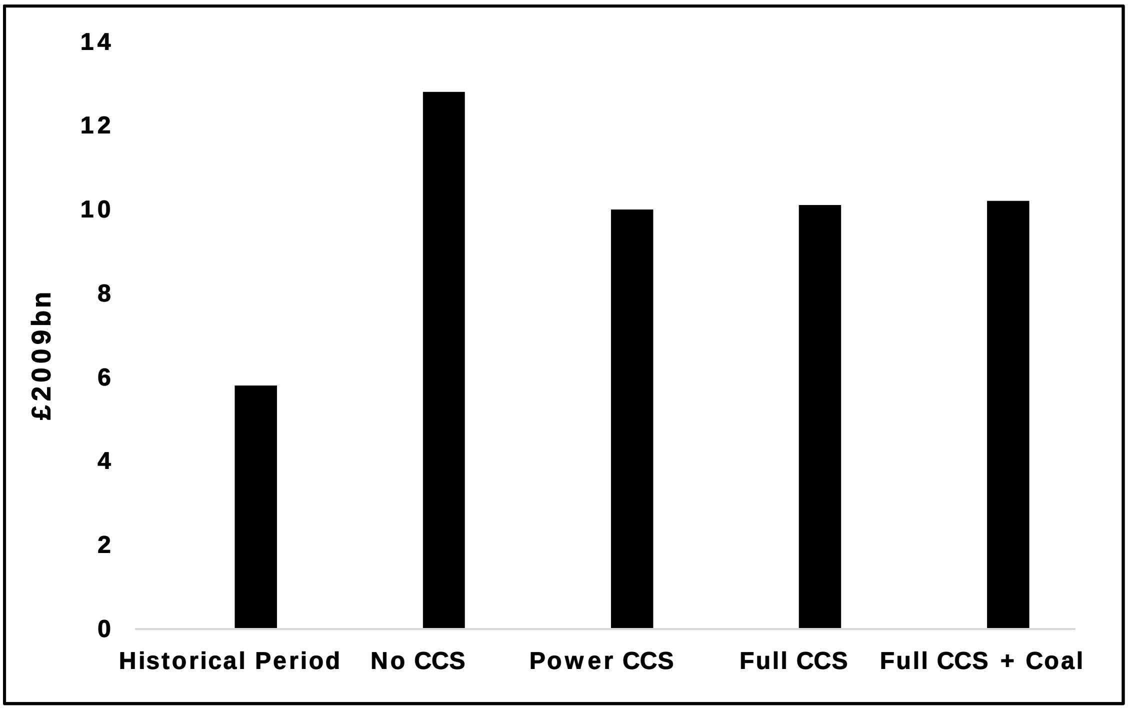


Figure 6: Average annual capital investment in the power sector[18]

[17] Cambridge Econometrics (forthcoming), Analysis of the national and regional economic impact of developing a UK carbon capture and storage sector. Note that the mix of technologies in the Full CCS scenario is almost identical to that in the Power CCS scenario, and so electricity prices in these two scenarios follow an almost identical path.

[18] Cambridge Econometrics (forthcoming), Analysis of the national and regional economic impact of developing a UK carbon capture and storage sector.

It should be noted that the cost effectiveness of CCS scenarios are dependent on the future cost of fuel (coal and gas). There will also be other economic benefits, such as increased number of jobs, improved national balance of payments and increased energy security if a proportion of energy demand is met through higher domestic fuel production. It will be important to couple use of CCS with support for a viable domestic fossil-fuel production industry (coal and gas) in order to reduce reliance on imports, and the associated volatility in price.

Reduced electricity costs result, not only in an increase in the disposable income of individual householders, but also ensures that businesses and industry can maintain their competitiveness in international markets. Results from the modelling suggest that UK manufacturing prices would increase by around 1% by 2030 in the absence of CCS in industry. In the commodities markets, in particular, there is no guarantee that industry can pass on these costs and remain competitive. This is particularly important for the UK's Energy Intensive Industries, and is discussed in greater detail in Section 5.4.

5.3 Employment and other socio-economic benefits

Significant direct, indirect and induced benefits[19] have been modelled for projected plant installations, supported by limited but growing empirical data from existing projects and project proposals.

- Direct benefits are gained from the construction and operation of facilities, and the associated demand for labour and materials.
- Indirect benefits result from spend from wages paid to workers; and additional labour and materials required by supply chain companies.
- Induced benefits for the local economy result from a boost to wages and local spending, and also include:
  - Foreign direct investment;
  - Development of an exportable UK CCS industry;
  - Avoidance of carbon leakage;
  - Potential uses of CO2 (such as EOR).

All these benefits result in increased income tax and a reduction in benefit costs for the Government. Details of different approaches to the calculation of socio-economic benefits are provided below (Models 1-4, and Case Studies 1 and 2).

Taken together, these can be **summarised** as follow:

Job generation from CCS in the power sector reaches a peak during the plant construction period (typically 4-6 years) with up to **2500 jobs** (range 1000-2500) per CCS power plant installation, depending on the nature of the project and fuel type (with coal plant generally requiring more supply chain investment than gas). For example, the White Rose oxyfuel plant (new modern coal-fired power station fully equipped with oxyfuel combustion and CCS technology) is estimated to generate a peak of 2478 construction jobs (average 1250), whereas for the Teesside Low Carbon project (development of a syngas plant and construction of a new CCGT) the peak estimate is in the region of 1000 jobs.

Estimates of longer-term employment at typical power plants with CCS tend to be in the region of 200–300 jobs in operation and maintenance (O&M) and the associated supply chain, of which 40–100 jobs are at the plant itself.[20,21] These estimates are given credence from the first actual power

[19] CO2Sense, The national, regional and local economic benefits of the Yorkshire and Humber carbon capture and storage cluster, October 2012.
[20] CO2Sense, The national, regional and local economic benefits of the Yorkshire and Humber carbon capture and storage cluster, Executive Summary, October 2012; Scottish Enterprise, Economic Impact Assessments of the proposed Carbon Capture and Storage demonstration Projects in Scotland – a Summary report, May 2011; information from Teesside and Don Valley projects.
[21] It should be noted that job generation figures relate to a new-build CCS power plant only, not a retrofit CCS power plant.

plant CCS installation at Boundary Dam in Canada,[22] which employed >1500 during the construction period, and maintains 41 operational employees.

Expected **installed capacity** in the UK to 2030 ranges from 10 GW (conservative) to 20 GW (ambitious but achievable).[23] This is consistent with the ambition of the CCS industry, as set out in the CCSA document 'A Strategy for CCS in the UK and beyond' published in 2011, which called for the need to build up to 20 GW of CCS in the UK by 2030.[24]

Assuming growth from 300 MW per installation (current day) to about 1 GW by 2020, this suggests a target in the region of 15 to 25 installations by 2030 (of which 10 to 20 are likely to be from 2020 onwards).

Total employment generated can be calculated for targets of both 10 and 20 GW of installed CCS capacity in the UK:

- Based on an average of 12,000 man years per installation (2000 per year over 6 years), this would imply 180,000 to 300,000 man years for construction over the period to 2030 (10 GW and 20 GW respectively), depending upon the average scale of a plant. For the period 2020-2030, assuming 20 installations, average construction employment would therefore be in the region of 24,000 a year.
- Longer-term operational jobs are anticipated to reach between 3750 and 6250 jobs/yr by 2030 (250 per installation).
- This gives total estimate of annual employment in excess of 30,000 by 2030 for 20 GW, a number that could be considerably augmented by jobs associated with exports.

However, it should be noted that these bottom up estimates are conservative in relation to previous analyses. For example, in their base case scenario, AEA suggest that implementation of just 10 GW of CCS between 2020 and 2030 will require 280,000 man years for construction, or an average of 28,000 construction jobs per year over the 10 years (Model 1).[25] Other estimates include 50,000 jobs in the UK by 2030 based on participation in the global market for gas and coal-based CCS plant (Model 2);[26] and 70,000 jobs by 2035 based on a trajectory for installation of 100-120 CCS plants in the UK by 2050 (Model 3).[27]

GVA is calculated using an estimation of the proportion of UK supply chain content in UK CCS projects (UK content). Most models assume between 35 and 75% UK content in the UK market, and 2-10% UK content in the global CCS market.

There is clear consensus that the UK can capture a high proportion of the market for engineering design, project management, procurement and commissioning activities, and will benefit from the potential cross-over with the skills currently used in the oil and gas industry. The manufacturing part of the value chain represents approximately 45% of investment costs. Future UK content of manufacturing is less certain although, for example, manufacture of amine solvents (often used in post-combustion CCS) is well established.[28] Nevertheless, the 75% UK content figure is considered feasible, since this matches both that obtained in the historic energy sector,[29] and the current target for the offshore wind industry.[30]

---

[22] http://sequestration.mit.edu/tools/projects/boundary_dam.html and personal communication
[23] Projections of 10 GW (approximate) installed CCS capacity by 2030 can be found in the DECC *draft EMR delivery plan*, July 2013 with a more ambitious target of 15 GW suggested by the Committee on Climate Change in *Next steps on Electricity Market Reform – securing the benefits of low-carbon investment*, May 2013. Projections of 20 GW installed CCS capacity can be found in the CCSA *Response to Energy and Climate Change Committee Inquiry into Carbon Capture and Storage*, Sept 2013.
[24] CCSA, A strategy for CCS in the UK and beyond, September 2011
[25] AEA, Assessing the Domestic Supply Chain Barriers to the Commercial Deployment of Carbon Capture and Storage within the Power Sector, DECC, September 2012; CCC targets, cited in CCSA Response to Energy and Climate Change Committee Inquiry into Carbon Capture and Storage, Sept 2013.
[26] AEA, Future Value of Carbon Abatement Technologies in Coal and Gas Power Generation to UK Industry, March 2010.
[27] IPA, Carbon Capture and Storage Skills Study, Alan Young, Richard Catterson and Mike Farley, Sept 2010.
[28] AEA, Assessing the Domestic Supply Chain Barriers to the Commercial Deployment of Carbon Capture and Storage within the Power Sector, DECC, September 2012.
[29] Calculation based on data contained in Office for National Statistics, Supply and Use Tables, 1997 – 2010.
[30] BIS Offshore Wind Industrial Strategy, April 2013.

Based on 75% UK content, GVA from the UK market has been estimated in the region of £2bn - £4bn a year by 2030 with a cumulative market value of £15bn to £35bn (10 GW and 20 GW respectively).[31] Global markets will offer substantial export opportunities. It has been calculated that 964 GW of total installed CCS power generation capacity will be needed globally by 2050 to reach required emissions reductions (IEA 2DS emissions reduction trajectory),[32] creating a market worth over £100bn per year from 2020,[33] much of it in developing countries. With a modest share of global markets UK GVA could increase to £5bn - £9bn/yr by 2030.[34] Long-term growth is anticipated to continue strongly to 2050, with the IEA estimating that 7 giga tonnes of CO_2 needs to be stored globally per year in both power and industrial sectors in 2050, reaching a total cumulative 120 giga tonnes of CO_2 stored, if CCS is to deliver its 17% share of emissions reduction.[35]

On an individual project basis, power sector CCS (including transport and storage) projects could deliver approximately **£150 million** a year GVA associated with construction (over a six year period), and **£200 million** a year from 2020 in operation (calculations based on FOAK project costs).[36]

Lastly, in a different approach that compares scenarios with and without CCS in 2030, and using optimistic assumptions in which associated benefits from CCS are realised from UK manufacture, domestic coal supply to the sector, and revenue from EOR, **GDP in 2030 was found to be £16bn higher by a scenario with CCS, than with no CCS**.[37]

Four different approaches to modelling GVA and employment associated with CCS deployment, and two case studies for CCS clusters are illustrated below. It should be noted that GVA calculations are based on assumptions for construction and operational costs. In the case of CCS, there is little empirical data, and therefore the considerable uncertainty over cost estimates is emphasised in all modelling exercises.

Model 1: Growth in CCS market, 2020 to 2030[38]

Based on an installed capacity of just 10 GW in 2030, the cumulative CCS market between 2021 and 2030 was valued at **£15.3bn** (in 2010 prices) with average annual market demand in 2030 reaching **£2.7bn**. This was associated with a theoretical **£10.9bn** growth opportunity for UK businesses (assuming capture of 100% of the supply chain for domestic demand). It was emphasised that the proportion that is actually captured by UK businesses is dependent on many factors, and whilst 100% is unlikely, the opportunity is significant, and will be enhanced by the growth of an export market if the supply base becomes well established. Approximately 280,000 man-years labour was be required over the same period, of which over 40% were in the construction part of the supply chain. In terms of skills, 72% were in mechanical engineering, process engineering and the construction sector (crafts). Other skills were required in offshore engineering, geology and legal and financial services.

If the installed capacity was set at a more optimistic, but achievable level of 20 GW by 2030, the cumulative value reached **£34.5bn with an annual market value of £5.8bn**.

---

[31] Based on AEA figures which assume a relatively high labour input (280,000 man years) for cumulative 10 GW installation.
[32] International Energy Agency, Technology Roadmap Carbon Capture and Storage – 2013 edition.
[33] Scottish Carbon Capture & Storage and The Scottish Government, Progressing Scotland's CO2 storage opportunities, March 2011.
[34] Based on 75% of AEA market value figures: AEA, Assessing the Domestic Supply Chain Barriers to the Commercial Deployment of Carbon Capture and Storage within the Power Sector, DECC, September 2012, and data from IPA, Carbon Capture and Storage Skills Study, Alan Young, Richard Catterson and Mike Farley, Sept 2010.
[35] International Energy Agency, Technology Roadmap Carbon capture and storage – 2013 edition.
[36] Scottish Enterprise, Economic Impact Assessments of the proposed Carbon Capture and Storage demonstration Projects in Scotland – a Summary report, May 2011.
[37] Cambridge Econometrics (forthcoming), Analysis of the national and regional economic impact of developing a UK carbon capture and storage sector.
[38] AEA, Assessing the Domestic Supply Chain Barriers to the Commercial Deployment of Carbon Capture and Storage within the Power Sector, DECC, September 2012.

Model 2: Global sales of advanced coal and gas power generation plant[39]

Value to the UK from worldwide sales of advanced coal and gas power generation plants with and without CCS was modelled. The model also included benefits associated with engineering consultancy for pre-feasibility and feasibility studies on new plant, the operation of CO2 storage facilities and financial and legal services. GVA was defined as value to the UK in terms of economic activity and employment, driven by the proportion of work (manufacturing, consultancy etc.) actually undertaken in the UK.[40]

Value to the UK increased from **about £1.5bn to over £5.1bn/yr** between 2010 and 2030, largely due to the uptake in CCS technology (both new build and retrofit). This was associated with total of about **70,000-100,000 jobs** in the UK in 2030, more than 50% of which were associated with CCS services (e.g. design and manufacture of capture, transport and storage facilities). Although the UK was expected to take a much larger share of the UK market (30-35%) than the global market (2%), due to the sheer size of the market, value from non-UK sales reached almost 80% by 2030.

Model 3: Extrapolation of 400 MW new build coal-fired CCS[41]

A 'bottom up' modelling approach used a theoretical new build 400 MW coal-fired power station with CCS, pipeline transport and storage in offshore depleted hydrocarbon fields, to calculate capital expenditure and job requirements. This was then extrapolated to calculate total UK GVA and jobs, based on securing all major contracts in a UK rollout of 100-120 projects by 2050, and 10% of the global market (totalling 260 projects). 10% was considered a realistic figure, based on experience in the oil and gas sector.

'UK plc' share of global business was found to be potentially worth more than **£10-14bn/yr** from around 2025, with the added value in the UK worth between **£5bn and £9.5bn/yr** at its peak (2020-2030) and dropping thereafter to between £2bn and £5.5bn once the major construction phase was completed.

The number of associated jobs in the UK was estimated as 27,000 by 2020 and 70,000 by 2035. A further 90,000 jobs could be secured by 2030 (increasing to 190,000 by 2050) outside the UK, based on eight additional CCS coal-fired power plant projects per year worldwide.

Model 4: Optimising the Positive impact of CCS in the energy mix[42]

The Cambridge Econometrics model (see Section 5.2) was also used to show the maximum economic benefits that could be obtained from an optimum scenario in which a number of co-benefits are realised.

Assuming:

- Domestic content supply of CCS capital goods reaches 75% by 2030;
- An increase in domestic coal production in the 'Full CCS with coal' scenario to meet the demand for coal by the CCS sector;

An increase in oil production, through CO2 EOR of 800 million barrels of oil in the UK by 2030;[43]

then GDP in 2030 was £16bn higher than the No CCS baseline.

[39] AEA, Future Value of Carbon Abatement Technologies in Coal and Gas Power Generation to UK Industry, March 2010.
[40] Discrepancies in the way that stakeholders may have interpreted the question 'What market share might UK industry expect to attain for new coal power plant projects?', may have led to an overestimation of GVA.
[41] IPA, Carbon Capture and Storage Skills Study, Alan Young, Richard Catterson and Mike Farley, Sept 2010.
[42] CE Reference, Sept 2013.
[43] This analysis assumes that around 2m barrels of oil are recovered using EOR in 2020, increasing to about 160m barrels by 2030. This is on the basis that all CO2 stored is used for EOR (annual storage of 740 ktCO2 in 2020, increasing to around 60 MtCO2 by 2030 in the Full CCS scenario).

Case Study 1: Yorkshire and Humber CCS Cluster[44]

The Yorkshire and Humber region is considered one of the best strategic locations for a CCS cluster within Europe, with large-scale coal-fired power generation and energy intensive industries in the region (totalling 60 Mt CO2/yr) already clustered together in close proximity, together with ready access to both EOR and saline aquifer storage in the North Sea. In addition to CO2 reduction, highly beneficial socio-economic impacts of such a cluster have been shown, using a Regional Econometric Model.

Economic benefits are greatest during the overlap between construction and operation when at least 6,000 net additional FTE jobs and £245 million net additional GVA are realised. The long-term regional economic impact (by 2050) could exceed £26 billion, sustaining and creating thousands of jobs across Yorkshire and the Humber.

Total direct and indirect economic impact: **£1.255 billion** to 2030, of which:

- Construction (2012-2019): £780 million
- Operation and maintenance (2019-2030): £470 million (£30 million pa)

Employment figures follow a similar trajectory with:

- Peak employment during construction of **6000**
- Permanent job creation of **400** (O&M)

At the heart of the model is a 'core' cluster consisting of pre-combustion carbon capture at a new 650 MW (net) coal gasification plant (Don Valley),[45] oxyfuel carbon capture at a new coal-fired power plant at Drax's Selby site (White Rose),[46] and 'right-sized' pipeline and offshore storage facilities in the North Sea.

These benefits will be felt throughout the region's supply chain, helping to consolidate and grow an industry base which already employs up to 24,000 individuals.

Regional Supply Chain Industries[47]

Supply Industries	**Structural metal; Fabricated metal products (e.g. pipelines); Machinery (e.g. pumps, compressors, valves); Electrical machinery; Civil engineering construction; Plant automation**
System Integrators	**Process Plant Project Management Sector**
Support Industries	**Specialist software; Carbon finance & legal; Monitoring & surveying; Technical development; Facilities management; Geological services**

In the medium to long term, the 'right-sized' approach to pipeline and storage facilities will ensure that this core cluster attracts new power generators and industry to the region and enables existing EIIs to reduce their CO2 emissions cost-effectively. For example, the development of a CCS cluster in Yorkshire and Humber would enable companies, such as Tata Steel's Integrated Iron and Steel Works (IISW) at Scunthorpe, to secure the future of **4,500 jobs**, and retain between **£250 million and £300 million GVA** a year.

[44] CO2Sense, The national, regional and local economic benefits of the Yorkshire and Humber carbon capture and storage cluster, Executive Summary, October 2012.
[45] http://www.2coenergy.com/don_valley_power_project.html.
[46] Capture Power Ltd., White Rose Carbon Capture and Storage Project, ENVIRONMENTAL SCOPING REPORT, December 2012.
[47] Adapted from CO2Sense, The national, regional and local economic benefits of the Yorkshire and Humber carbon capture and storage cluster, Executive Summary, October 2012.

Indirect benefits and foreign direct investment were estimated to:

- Support 11,000 existing jobs and create 2,000 new jobs within the CCS supply chain by 2030;
- Result in £870 million in net additional output per year by 2030 - raising Yorkshire and Humber's output by 0.8% annually.

In the long term, technology companies, engineering specialists and business support services associated with CCS will become embedded in the area, as well as emerging industries with specialist use for CO2 within their industrial processes.

Case Study 2: CCS in Scotland[48]

Three proposed CCS demonstrations in Scotland were together estimated to provide up to £2.7bn GVA during the 6 year construction period (with a maximum of 4600 jobs) and over £500m a year thereafter (associated with 450 jobs).

The three plants, Longannet, Peterhead and Hunterston, were all based on retrofit post-combustion capture using amines. Transport via new CO2 pipeline (Hunterston) or the transformation of existing gas pipeline, led to storage in refurbished hydrocarbon fields in the North Sea. It was assumed that relatively high capital costs would be incurred by these early demonstrations:

- Longannet subcritical coal fired power station (Scottish Power) in Fife with 300 MW CCS: £1.2bn (£600m capture; £300m transport; £300m storage).
- Peterhead gas fired power station (SSE) in Aberdeen with 300 MW CCS: £700m (£300m capture; £200m transport and £200m storage (shared with Longannet)).
- Hunterston supercritical coal fired power station (Ayrshire Power Ltd) in Ayrshire with 385 MW CCS: £1.5bn (£600m capture; £700m transport; £200m storage).

These capital costs were used as the basis for calculating GVA, using assumptions for the % share accrued by different supply chain activities (engineering, project management, procurement, manufacturing, construction and commissioning), and the percentage share of that value that Scottish companies could expect to gain access to. As a result of experience in the oil and gas industry, Scotland was expected to achieve particularly high GVA from the transport (60% to 90%) and storage (64% - 95%) elements of the CCS chain. Conversely only 24-30% of the GVA generated from the capture infrastructure was considered likely to be captured in Scotland.

Table 1. GVA and Jobs in Scotland from the Construction and Operation Phases of all three demonstration projects (Longannet only in brackets)

		Construction over 6 years	Lifetime Operation
GVA	Direct GVA	£1,412m (£450m)	£230m/pa (£120m)
	Indirect GVA	£628m (£210m)	£243m/pa (£120m)
	Additional induced GVA	£716m (£230m)	£62m/pa (£40m)
	Total	**£2756m (890m)**	**£535m/pa (£280m)**
Jobs	Direct jobs	3040 (966)	120 (51)
	Indirect jobs	1150 (450)	236 (102)
	Additional induced jobs	410 (130)	99 (43)
	Total	**4600 (1546)**	**454 (196)**

[48] Scottish Enterprise, Economic Impact Assessments of the proposed Carbon Capture and Storage demonstration Projects in Scotland – a Summary report, May 2011.

'Shovel Ready' Projects

A considerable amount of time and £10s of millions have been spent in designing CCS projects in the UK, and there are currently in the region of 5-7 'shovel ready' power and industry based CCS projects, involving multinational power, oil and gas, and gas transport companies. Given sufficient support, these could provide the impetus needed to kick start the 'Green Growth' agenda providing skilled employment within the regional industrial heartland over the next decade.[49]

Taking the estimates for the FOAK plants given in the Scottish cluster case study, on a single project basis, this equates to approximately **£150 million** a year GVA associated with construction (over a six year period), and **£200 million** a year from 2020 in operation, including transport and storage.

Empirical data

In all of the above cases, modelled data has been used to generate predictions of employment and GVA. In Canada, however, the first commercial scale power CCS project, a 110 MW coal power plant with retrofit CCS technology, has been completed and is due to start operating in 2014. The total cost of the project is estimated to be $1.24 billion, with $240 million provided by the federal government in 2011, of which about $180 million has already been spent. Although a relatively small plant, direct employment to date has been 20 at the R&D stage, 1500 during peak construction and 41 operational employees.

In summary, the GVA and employment potential associated with CCS is highly significant. The UK has viable projects that are ready for implementation, and that have the potential to provide jobs and revenue to the UK over the next decade. Realisation of these early commercial demonstrations will require development of a stable indigenous supply chain. This in turn would put the UK in a leadership position, allowing it to take first mover advantage in a rapidly growing and extensive global market. Delayed action, on the other hand, will inevitably result in market share being lost to competitors, in the U.S., China, Canada, and Australia, in particular.

5.4 Maintaining fossil-fuel and energy intensive industries (EIIs) in the UK:

Fossil fuel power with CCS

CCS is vital to enable fossil fuels to continue to play an important role in meeting ever-increasing energy demand in an environmentally-sustainable manner.

The UK relies on gas-fired power for a large proportion of its electricity supply, with gas regularly supplying more than 30% of the UK's electricity. The Government published a Gas Strategy in December 2012, in which it is suggested that up to 26 GW of new gas-fired capacity could be required by 2030.[50] Gas-fired power has a central role to play in meeting energy demand, and gas-CCS therefore plays a vital part in meeting the UK's statutory target to reduce greenhouse gas emissions by 80% by 2050.

The proportion of electricity supplied by coal-fired power stations is similar to that supplied by gas, averaging 38% in 2012, but this has regularly been ramped up to more than 50% at peak times during winter.[51] Under the Large Combustion Plant Directive (2001/80/EC), several UK coal stations, (8 GW out of the current total of 28 GW) will have closed well before the end of 2015. In addition, the Industrial Emissions Directive (2010/75/EU) will continue to impose increasingly stringent emissions targets (SO_x and NO_x). This, together with uncertainty over future carbon prices is likely to lead to significant further closures by 2023.

The UK coal mining industry produces around 17 million tonnes of coal a year from four deep mines and several surface mines, about one-third of UK coal consumption. The industry currently

[49] "Shovel ready" is a term used to describe a "construction project (usually larger-scale infrastructure) where project planning, engineering and funding have advanced to the stage where labourers may immediately be employed to begin work". "Green Growth" is a term used to describe "a path of economic growth which uses natural resources in a sustainable manner" (Wikipedia.com).
[50] DECC, Gas Generation Strategy, December 2012.
[51] TUC Clean Coal Task Group, Coal & CCS in the Energy Bill.

employs a highly skilled workforce of more than 6000. Together with coal power industry and logistics, this reaches a total of 11,000 direct and indirect employees[52].

Both gas and coal are also important flexible sources of generation to complement inflexible (nuclear) and intermittent renewable (offshore wind and solar) generation. Fossil fuels with CCS will therefore continue to be important in balancing the electricity generation mix going forward.

However, it is clear that unabated fossil fuels (both coal and gas) cannot continue to operate indefinitely if we are to mitigate climate change. The UK has already implemented a number of policies to prevent the construction of new unabated coal-fired power stations and the Committee on Climate Change has stated that that 'extensive deployment of unabated gas-fired capacity (i.e. without carbon capture and storage technology (CCS)) in 2030 and beyond would be incompatible with meeting legislated carbon budgets'.[53]

The deployment of coal and gas with CCS is therefore associated with the opportunity to prolong the life of important indigenous fossil fuel industries, securing a valuable UK fossil-fuel resource base that will otherwise be lost, and maintaining a significant number of jobs.

Enhanced oil recovery (EOR)

Captured CO2 may be used in Enhanced Oil Recovery to access previously uneconomic hydrocarbon resources. This has been explored extensively in the US and Canada onshore oilfields, where it forms the basis of many of the existing CCS projects, and where the revenue provided for CO2 is crucial in the development of a viable business case for the entire CCS value chain.

In the UK, EOR has the potential dual benefit of enabling low-carbon power generation, whilst extending the life of the indigenous oil and gas industry, and associated offshore service industry. The UK's Central North Sea (CNS) oil province is mature with many fields set to close in the next decade. This area is ideally located for CO2 transport from the North East of England and Scotland power generation and industry clusters. It has been estimated that an additional 3-5 billion barrels of oil (£200-300bn at $100/barrel) could be delivered from the North Sea with EOR.[54] Assuming that 0.7 Mt of CO2 would be available in 2020, rising to 60 Mt/yr by 2030, approximately 800 million barrels of this would be recoverable by 2030.[55] The resulting benefits would include tax revenues, employment, delayed decommissioning, and an enhanced UK balance of payments.

However, not all CNS fields are suitable for EOR, and there is considerable uncertainty over the value CO2 may attract, if delivered at pressure to CNS oil field operators, and the mechanisms by which this value would be split between government, CO2 provider and EOR developer. Nevertheless, the possibility remains that EOR could cover the cost of conventional CO2 storage, and perhaps some of the transport costs as well. The CCS Cost Reduction Taskforce suggests that CO2 EOR could reduce electricity costs by £5-12/MWh for gas CCS and £10-£26/MWh for coal CCS. More information is urgently needed on the viability of CO2 EOR, and several oil companies are actively exploring options in the UK.

Energy intensive industries (EIIs) and industry CCS

Energy intensive industries in the UK form the backbone of the UK manufacturing economy, and produce primary inputs for much of what we manufacture and consume in some of the most advanced plants of their kind globally. They also provide essential supply chain products for many low-carbon technologies, such as steel and concrete for wind turbine installations, glass for double glazing and fibres for loft insulation.

The principal sectors are:

- Iron and steelmaking
- Cement and lime manufacture
- Chemicals

[52] TUC Clean Coal Task Group, Roadmap for Coal, October 2011.
[53] http://archive.theccc.org.uk/aws/EMR%20letter%20-%20September%2012.pdf.
[54] CO2Sense, The national, regional and local economic benefits of the Yorkshire and Humber carbon capture and storage cluster, Executive Summary, October 2012.
[55] Cambridge Econometrics (forthcoming), Analysis of the national and regional economic impact of developing a UK carbon capture and storage sector, using data from pervious Element Energy studies.

- Ceramics
- Glass
- Non-ferrous metals (such as aluminium, zinc and lead)
- Pulp and paper
- Coke and refined petroleum product industries

By their very nature, these industries use large amounts of energy (electricity and gas) in their manufacturing processes or as raw material. They account for roughly half of UK industrial energy consumption and produce 55 Mt CO2/yr, equivalent to 66% of UK's industry total, and 10% total greenhouse gas emissions.[56]

Industry makes up nearly 25% of UK carbon emissions, and by 2050, Government expects reductions of 70% from 2009 levels. Most of the emissions reduction that can be achieved by energy efficiency has been implemented, and from a technology perspective, CCS offers the greatest opportunity for carbon dioxide abatement within these sectors.

It has been calculated that CCS has the potential to address up to 38 Mt of industry's CO2 emissions a year in 2030 at costs of between £30 and £150 per tonne of abated CO2.[57] However, the viability of CCS, both technologically and economically, varies between sectors. For example, ammonia production and chemical processing are well suited to early adoption, since CO2 is already captured as part of the manufacturing process, and cost for these plants is mostly related to transport and storage. As the cost of capture is extremely low, these sectors can be considered low-hanging fruit for CO2 capture compared to other, more expensive sources. Other potential sectors for industry CCS include refineries, CHP, and cement and lime. All these sectors contain individual plants which produce in excess of 50,000 tCO2/yr.

In the UK, many EIIs are ideally placed for development of CCS, being already located in regional clusters, together with power stations, in close proximity to North and Irish Sea offshore storage locations (see Case Study 3: Tees Valley).

In terms of the decarbonisation of industrial sectors, energy efficiency and fuel switching are the first options to be considered. However, in the majority of cases, all viable opportunities to reduce emissions through these two options have already been undertaken, and the only possibility for further significant emissions reductions is through CCS.

Cost of industry CCS

There is considerable variation and uncertainty over the capture cost of industry CCS, primarily because of numerous site-specific factors that need to be considered, including CO2 purity, scale, technology type and site readiness.[58] In particular, the additional heat energy requirements for CO2 capture is crucial, since this may either be met through process heat or existing CHP, or require installation of entirely new CHP plant.

The application of CCS to industry therefore varies between sectors; some need to develop and trial a range of capture technologies while others could deploy CCS almost immediately if the right policies were in place, for example:

- Iron and steel: top gas recycling blast furnace coupled with CCS.
- Cement manufacture: through post-combustion capture technology using amines to remove CO2 from gases, or oxy-combustion.
- Chemicals: where a number of processes are good contenders for post-reaction capture due to large volume, highly concentrated CO2 streams.

Even more important is the cost to industry of the transport and storage elements of the CCS chain (construction and operation). Given the size of individual plants and the associated lower CO2 volumes (compared to power plants), it is unlikely that industrial CCS can be developed in the

---

[56] TUC, Building our low-carbon industries, THE BENEFITS OF SECURING THE ENERGY-INTENSIVE INDUSTRIES IN THE UK, June 2012.
[57] DECC, CCS Roadmap 2012.
[58] Element Energy, The costs of Carbon Capture and Storage (CCS) for UK industry - A high level review, report for BIS and DECC, March 2013.

absence of a shared transport and storage network, with a large emitter (e.g. power plant) at its core. The network needs to be safe, affordable, of the right size, in the right location and commissioned at the right time.[59] This is turn requires certainty over regional volumes of CO2 production to 2030 and beyond, difficult to achieve in an environment in which sources may close, relocate, change fuel type, improve efficiency, change output, and entirely new emitters may emerge (e.g. biofuel refining).

The regulatory environment

Carbon reduction from the energy intensive industries in the UK is primarily regulated via the EU ETS, a cap and trade framework that requires operators to surrender EU Allowances (equal to one tonne of CO2) on an annual basis, in line with their reported emissions inventory. EUAs must be purchased above an allocated free allowance. To date it has been argued that the low price of carbon (less than £4 per tonne of CO2 in 2013),[60] is not providing sufficient incentive for investment in low-carbon technologies. During Phase III (2013-2020), the cost of carbon is expected to rise significantly, potentially reaching £70 per tonne.[61]

CO2 in permitted CCS installations would not incur EUAs, and CCS therefore offers a potentially cost effective route to managing the cost associated with carbon emissions, provided that future carbon prices are sufficiently high. In other words, investment in CCS will be economically justifiable if the cost of capture and disposal is less than that of purchasing EUAs to cover the cost of emissions.

In view of the current weakness of the EU ETS, however, the UK has unilaterally introduced the Carbon Price Support (essentially a tax on the use of fossil fuel in power generation) which also aims to incentivise large scale investment in low-carbon technologies, including CCS (see Section 3).

Current government policies therefore rely heavily on increasing the cost of carbon emissions to encourage firms to invest in low-carbon and energy-efficient technologies. In practice, however, this approach reduces the capacity of these industries to invest and, when applied unilaterally, can distort their ability to compete internationally. The result is an increased risk of carbon leakage (see below).

In mitigation, the UK Government has introduced a £250m support package, spread over the current spending review period. This includes £75m in relief from the Climate Change Levy up to 2017, worth about £20m a year, and up to £100m (from April 2013) to counter the impacts of the carbon price floor on electricity costs for businesses that are electricity intensive and operate in internationally competitive markets. Nevertheless, there is concern that this remains highly inadequate relative to the more substantial and more consistent long term support given to EIIs in other countries, notably our leading competitor, Germany.

EIIs and impact of carbon leakage

Carbon leakage describes the re-location of carbon intensive industries from an area with stringent controls to a region with lower environmental costs of operation. This not only results in loss of jobs and revenue, and increasing import costs to the host country, but may effect an increase in global emissions through the use of inferior processes, more carbon intensive electricity, and greater transport of goods.

Many EIIs are multinational concerns, involved with the production of global commodities and must therefore compete intensely with other international players. In addition to direct emissions abatement regulations, EIIs are extremely sensitive to the cost of electricity, which can represent up to 80% of operating costs.[62] Since it is not possible to pass such costs on to their customers,

[59] Element Energy Ltd, The costs of Carbon Capture and Storage (CCS) for UK industry - A high level review For BIS and DECC, March 2013

[60] http://www.businessgreen.com/bg/news/2258336/carbon-floor-price-launches-at-gbp16-per-tonne

[61] CCS Cost Reduction Taskforce, The Potential For Reducing The Costs of CCS in The UK, Final Report, May 2013.

[62] TUC, Building our low-carbon industries, THE BENEFITS OF SECURING THE ENERGY-INTENSIVE INDUSTRIES IN THE UK, June 2012.

re-location is often seen as a good strategic option if conditions are more favourable elsewhere. In the case of many UK EIIs, these decisions are in the hands of international headquarters.

The combined impact of EIIs in the UK

The loss of EIIs from the UK would have immense ramifications.

EIIs make a direct contribution to the social and economic fabric of the UK, not only through their valuable industrial output but also through the skilled jobs they provide, the pay and benefits their employees receive and the significant fiscal contributions they make to HM Treasury. There is also evidence that EIIs are important contributors to skills development and training, and they act as anchors for industry-wide innovations, but only if there is a critical mass of companies remaining within each sector.

EIIs are often very large scale and/or clustered together to benefit from shared infrastructure and resources (e.g. ceramics and glass). As such they are often the dominant employer and source of GVA in a particular region, and exert significant influence on regional (often rural) economies.

The socio-economic value of all EIIs in the UK has recently been analysed.[63] Together they provide:

- Combined turnover of £95bn – 20% of UK manufacturing total, and 3% UK GDP.
- Direct employment of 160,000 people in well-paid, highly skilled jobs.
- Indirect employment of 800,000 people via supply chains.
- Combined GVA of £14bn in 2008, or 11% of the UK manufacturing total – as capital intensive industries they generate higher than average added value in their production processes.
- Very strong purchasing power of £68.6bn (2008), or a fifth of the UK manufacturing total.
- Employment costs of £6.6bn (2008) in wages, national insurance and pension contributions, or an average of £38,000 per employee.
- Corporate taxes and levies of £12bn in 2008 from the Climate Change Levy and other taxes, or around half (47%) of all manufacturing taxes.

Overall, the TUC and the Energy Intensive Users Group (EIUG) estimate that the economic and fiscal costs associated with the loss of EII employment would amount to a loss of output of more than **£77,000 per employee**.

Iron and steel and cement are two of the most energy intensive sectors in the UK, and Tees Valley is one of the most important concentrations of manufacturing in the UK. These provide good examples of the possibilities of industrial CCS, and are described below.

Iron and Steel and Cement

The UK iron and steel sector is dominated by global players, such as Tata Steel Europe, and is concentrated in the North East and Wales, with three integrated steel making plants and five secondary steelmaking sites. All are foreign owned except Sheffield Forgemasters. The three major steel plants are all considered suitable for CCS, with Scunthorpe and Redcar ideally located near the North Sea oil fields and potential power sector regional CCS infrastructure (the Yorkshire and Humberside, and Teesside clusters respectively, see Case Studies 1 and 3).

The UK cement industry is responsible for about 7 MtCO2 per year (1.7% of UK total emissions). Emissions are created both from fuel combustion and limestone calcination in kilns. Both of these offer the potential for carbon capture and storage or conversion. Capital costs of CCS capture plant (including base costs for the cement plant) range from approximately £300m (oxyfuel) to £500m (post-combustion) with emissions avoidance efficiency of 52% and 77% respectively.

The addition of CCS in the cement industry would have both economic and social benefits for the UK. The cement industry already supports over 2500 direct employees, the majority in rural areas, and in terms of labour productivity (GVA per employee), the cement and lime manufacturing sector lies well above the national average (£48.8k) at £110k.

[63] TUC, Building our low-carbon industries, THE BENEFITS OF SECURING THE ENERGY-INTENSIVE INDUSTRIES IN THE UK, June 2012.

However, despite a 29% increase in energy efficiency between 2005 and 2011, energy costs still represent nearly 40% of GVA. Electricity costs form over 60% of all energy costs. The combination of high electricity costs and high carbon prices therefore poses a real risk to the ability of UK cement production to remain internationally competitive. A recent statement by the Mineral Products Association underlies this point 'Full decarbonisation of the electricity generation sector should not increase the costs to industrial electricity consumers more than their international competitors'.

In the UK, cement and lime production is concentrated in twelve cement kilns and eight blending sites, plus seven producing commercial lime. Cement ownership is dominated by international companies and one UK-owned company. The loss of any single plant would therefore represent a significant proportion of jobs and GVA. The lime industry has a good export record from its nine production plants and, whilst there is some international ownership in the sector, most producers are UK companies.

Case study 3: Tees Valley

The Tees Valley represents one of the most important concentrations of manufacturing industry in Europe. The area provides around 28,000 direct manufacturing jobs per year, contributing £10bn to GVA (25% of all GVA from the North East of England).

Around 25 existing EIIs form the core of this activity, with particularly strong representation in the petrochemical, pharmaceutical, and specialty chemical sectors. These businesses employ nearly 7,000 people and add approximately £670m GVA/yr to the North East economy.

As a result, the region's carbon intensity is the highest in the UK, with eight businesses exceeding an average of 1 Mt/yr, and the region is thus particularly exposed to the effects of CO2 regulation and pricing. For example, payments for compliance with the EU ETS for Teesside businesses was estimated at around 44% of total GVA, a significant cost burden. The risk posed by carbon leakage from the North East is considered very significant, potentially resulting in a loss of around £5.4bn GVA over the period of the EU ETS Phase III (2012-20).

A proposed Teesside CCS low carbon cluster project has been developed by Progressive Energy in partnership with BOC, International Power, and Premier Oil, focussed round a new 850 MW Integrated Gasification Combined Cycle (IGCC) power plant with pre-combustion capture. In addition to 250 direct jobs and 1000 construction jobs associated with the project itself, the plant would crucially create a viable CCS infrastructure to capture up to 15 Mt/yr CO2 from the major industrial carbon emitters in the region, helping to securing their viability in the UK and the associated 28,000 process industry jobs.

5.5 Clean hydrogen production

Since hydrogen is produced as a by-product of pre-combustion CCS, the technology has significant potential become a source of low cost and clean hydrogen. Hydrogen is currently required in a number of industrial process, but in the longer term, significantly greater quantities will be needed for fuel cell based CHP systems and fuel cell vehicles.

The ETI ESME Model: CCS is a key enabler of clean hydrogen

The ETI's ESME model (see Section 5.2) points to the importance of CCS in providing cost effective hydrogen for transport and industrial uses.

In the Full CCS scenario, hydrogen production reaches 212.2 TWh, distributed amongst:

- Cars (148.8 TWh)
- Industry (57.6 TWh)
- Power (5.8 TWh)

This contrasts strongly with the No CCS scenario in which only 13 GWh (0.013 TWh) is produced in 2030.

Although the electrification of road transport has an important part to play in reaching the UK's carbon reduction targets, without fuel cell vehicles (hydrogen vehicles which use a fuel cell to produce electricity) as a feasible alternative transport option, the number of electric powered vehicles (EVs) on the road would be extremely high. EVs are not only more expensive to produce than FCVs, but an EV only scenario significantly raises total electricity demand, reducing flexibility and putting increased strain on the transmission network.

In the absence of CCS, this demand increase is likely to be exacerbated by industry which must also use electricity as the only option for decarbonisation. In comparison with the Non CCS scenario (800,000 TWh/yr), all three CCS scenarios resulted in significantly reduced **total** electricity demand by 2050, but the effect was most pronounced when industry CCS was included (< 600,000 TWh/yr) (Figure 7)

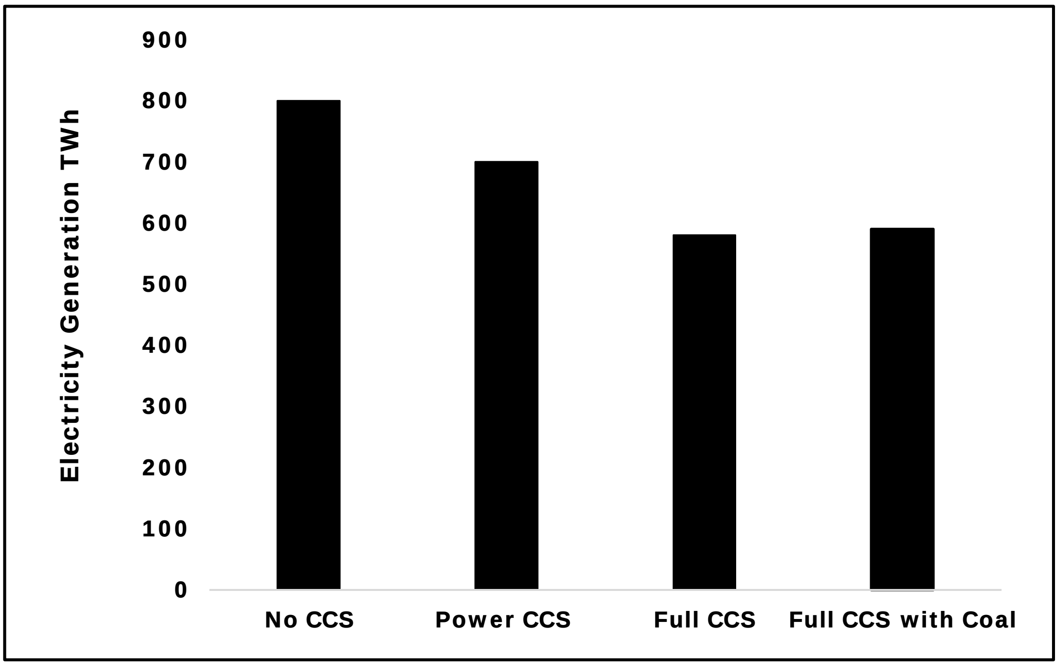


Figure 7: Electricity Generation in 2050[64]

5.6 Summary: CCS is needed to deliver low cost, secure energy with associated green growth

CCS can deliver on multiple Government objectives:

- Least cost decarbonisation.
- Energy security and meeting the near term energy gap.
- Green growth and safeguarding existing core industries.

Failure to deliver CCS as a mitigation option in the UK will have therefore have profound implications for the UK economy.

It has been shown that delivering emissions reductions at the levels sought within the UK, Europe and globally without CCS results in a significant increase in costs, and that this increase will in turn impact directly on consumer bills (domestic and industrial). Delaying deployment of CCS until the 2020s or 2030 and then attempting to deploy at a faster rate could impact negatively on costs as the supply chain becomes overstretched.

Fossil fuels are central to a robust, flexible and diverse electricity system. Without CCS their limited role in the energy system will impact negatively on the security of electricity supply. For many parts of the industrial sector, CCS is the only technology which will enable significant emissions reductions.

But in addition to these negative consequences of not implementing CCS, it is becoming clear that there are significant potential socio-economic gains to be realised from an energy system that includes CCS. These are associated with:

[64] Adapted from Cambridge Econometrics (forthcoming), Analysis of the national and regional economic impact of developing a UK carbon capture and storage sector. Inputs to the CE MDM-E3 model are based on results from the ETI's optimising ESME.

- Direct and indirect employment and GVA from construction and O&M activities associated with all parts of the CCS chain.
- Substantial regional GVA and employment safeguarded as a result of maintaining a strong presence of EIIs in the UK.
- The indigenous fossil fuel production industries: in particular coal mining, which is unlikely to make any future long term investment under present policies; and the potential for prolonging the life of North Sea oil fields through the use of CO2 EOR.

The UK has a number of 'shovel-ready' CCS projects that could be implemented over the lifetime of the next parliament, stimulating short-term growth in employment and regional GVA whilst putting in place the building blocks for realising the longer-term benefits.

6 Current Government support measures

DECC has laid out its intended mechanisms for supporting CCS development and deployment in the 2012 Roadmap.[65] Their 'five pronged approach' aims to reduce costs, create an effective market framework and address the key barriers to implementation through:

- A CCS commercialisation programme based around £1bn competitive funding for commercial scale projects. This aims to reduce future project risk through creation of legacy infrastructure, demonstration of viable commercial structures and testing of the regulatory framework.
- A £125m, 4-year, co-ordinated R&D and innovation programme.
- Development of a market for low-carbon electricity that will allow CCS to compete with other low-carbon technologies, primarily via appropriate FIT CfDs for CCS within the EMR.
- Support for the development of an effective supply chain; transport and storage networks; an incentivising regulatory environment; and an appropriate market framework for industry CCS.
- International engagement and knowledge sharing.

The CCS Cost Reduction Task Force was established as a collaboration between DECC, the Crown Estate and CCSA to investigate the activities needed to make CCS cost competitive with other low-carbon technologies in the 2020s. As described earlier, their final report demonstrates clear belief that sufficient cost reduction is achievable in the 2020s provided that critical actions are undertaken by both Government and industry stakeholders. Of particular importance are:

- Development and optimisation of a CCS transport network and associated storage hubs.
- Public support for early commercial projects (FOAK), including measures to reduce risk and improve investor confidence.
- Exploitation of the potential for use of CO2 in North Sea EOR.

The two most important support instruments for near commercial CCS are the commercialisation programme and the development of a market for low-carbon electricity via FiT CfDs.

Significant funding has been earmarked for major CCS projects over the last six years in the UK, but none has yet been awarded. In the UK, the 1st CCS competition was launched in 2007 with the intention of funding one project. Two projects were awarded FEED contracts in March 2010 (worth £40m), but E.ON (Kingsnorth) withdrew the following October, and negotiations were terminated with Scottish Power (Longannet) in October 2011 as commercial terms could not be reached between the Government and Longannet consortium.

The £1bn was subsequently made available to fund a second competition, with details of the two FEED studies made publicly available in order to ensure that insights were disseminated and learning from the projects maximised. To this end, DECC has framed the competition within broader CCS Roadmap objectives that include addressing key barriers around risk and regulations. Eight bidders entered the first round of the second competition (April 2012), four were shortlisted, and finally two preferred bidders (Peterhead in Aberdeenshire and White Rose in Yorkshire) were selected in March 2013. Negotiations are currently underway to agree terms for the FEED studies. A final investment decision (FID) is expected early 2015 for up to two projects, and if successful, projects should become operational between 2016 and 2020.

The FiT CfD mechanism is the key element in the Electricity Market Reform framework through which the government aims to ensure secure, low cost and decarbonised electricity against a backdrop of overall increasing demand (see Section 3). It ensures that operators are paid a minimum agreed price for low-carbon generation over the lifetime of the plant.

The CCS Roadmap outlines plans to ensure that the CfDs are adjusted appropriately to take into account the commercial risks associated with CCS. However, the details are yet to be resolved, with uncertainty remaining over the strike price itself and way in which reward via the CfDs can be transmitted down the disjointed parts of the CCS chain (capture, transport and storage). The Roadmap also falls short of providing specific installed capacity targets that could help drive deployment, and provide certainty for investors, and provides no proposals for incentivising industry-based CCS.

These and other requirements for the successful and rapid development of the CCS sector are discussed in Section 7.

[65] DECC CCS Roadmap, Supporting deployment of Carbon Capture and Storage in the UK, April 2012.

7 Actions required to achieve full CCS deployment

The development of a flourishing CCS industry in the UK represents a major investment in UK infrastructure. Government and industry need to work closely together to ensure this investment is managed in the best possible way, understanding how risks are minimised and shared.

In the absence of existing commercial scale plant, current risks to investors are very high. They can be categorised as uncertainty associated with:

- Cost: capital, operational, and finance.
- Returns on investment, i.e. the price for low-carbon electricity or heat.
- Transport and storage flexibility, including options for switching if necessary.
- Future utilisation, i.e. the risk of stranded assets.
- Appropriate business models for coordinated delivery of each part of the CCS chain.

These requirements are mirrored by the findings of the CCS Cost Reduction Task Force, which produced compelling evidence that the cost of CCS can be competitive with other low-carbon technologies by the early 2020s, provided that action is taken to: develop a strategic approach to the optimisation of a CCS transport network and associated storage hubs; provide public support for early commercial projects, including measures to reduce risk and improve investor confidence; and exploit the potential for use of CO2 in North Sea EOR.

The UK has reached a defining moment for the future of a national CCS industry. Decisions taken now, and actions taken over the next 7-10 years, will determine whether the UK takes advantage of its natural assets (physical and human) to realise the investment, employment and export potential of CCS. Fast action is needed to benefit from ‘first mover advantage’.

Government policy currently, while strong in parts, is not sufficiently developed to realise this vision. There are still considerable gaps in the actions being taken, and in the timeframe of delivery. The following actions are recommended for prioritisation by the Government.

7.1 A strongly endorsed long term vision

CCS project lead times are very long, often taking a number of years from initiation to operation. Despite many years in the preparation of large scale CCS projects in the UK (see Section 6), none have yet reached the ‘Final Investment Decision’ stage and investor confidence is at a low ebb. It is therefore essential that the Government now provides unambiguous recognition of the role of CCS in the future energy mix, as well as clearly defined public sector support for early projects, and longer-term incentives.

There is currently no clear articulation of Government ambition for CCS. The latest delivery plan for the EMR contains 2030 scenarios showing either no CCS projects delivered beyond the current commercialisation programme or an industry with 12 GW capacity – and such a range is unlikely to send the necessary signal to CCS developers.

Within the literature, 10 GW by 2030 has been suggested as a conservative level of deployment, with a more ambitious, but achievable target of 15 GW set out by the Committee on Climate Change,[66] and 20 GW suggested by the CCSA[67] and endorsed by the TUC. Given the long lead times, all parties need to move swiftly if there is to be a realistic chance of achieving this target.

7.2 Early deployment and steady rollout

Although improvements in cost can always be achieved through ongoing R&D, there is broad consensus that CCS technology is ready for commercial scale demonstration.

Early stage demonstration projects (also known as First of Kind or FOAK projects) have high capital costs that reflect their novel nature, limited size, and lack of industry track record. Support by the public sector is essential in reducing their risk exposure in order to facilitate learning-by-

[66] Committee on Climate Change, Next steps on Electricity Market Reform – securing the benefits of low-carbon investment, May 2013

[67] CCSA Response to Energy and Climate Change Committee Inquiry into Carbon Capture and Storage, Sept 2013.

doing and culminate in a technology that can be sold in the marketplace with appropriate commercial structures and performance guarantees bankable for investors.

In addition to the two CCS projects that have been selected as preferred bidders within the DECC CCS commercialisation programme, the UK has 3-5 projects that could be implemented within the framework of the next parliament.

The original estimate of the CCC and intention of the Coalition Government (and indeed, the preceding Labour administration) was that support for four early stage CCS power generation projects was required to provide sufficient critical mass to kick start full commercial deployment of CCS from 2020s. It is thus essential that provision is made for these non-competition projects to develop in parallel, in order to capitalise on the investment already made. Delays will result in the loss of valuable engineering and build skills, and first-mover advantage, as well as potential investment worth many £bns. In addition, these projects can be thought of as the second phase of CCS deployment in the UK (with the two projects in the competition as phase 1) and it is vital that these 'phase 2' projects are built to ensure a smooth transition to phase 3 and onwards.

Steady rollout is also crucial to the development of a strong, indigenous, supply chain by creating a stable market for associated products and services, and ensuring that investment is maintained by suppliers. A stop start approach on the other hand risks creating damaging boom and bust cycles or the risk that the supply chain will simply not be available or sufficiently skilled up when needed. This applies to skills as well as products and services: although the UK has an appropriate engineering base, the provision of specialist training courses and/or the transition of skilled individuals from the other energy sectors can only be accomplished against a progressive CCS build out programme within a defined timeframe.

7.3 Market certainty

The principal public support mechanism for creating a clear return on investment for CCS projects is the EMR's proposed FiT CfD mechanism. However, the EMR currently lacks guidance on CfD price setting and allocation process for CCS projects,[68] and there is also concern that the CfD designed for renewable energy projects is not suitable for the cost structure of CCS projects which, unlike wind or nuclear technologies, have variable operating costs as a result of fossil fuel inputs.

In the absence of capital support for non-CCS competition projects, it is vital that the CCS CfDs are able to provide sufficient security to enable continued investment in these early stage projects:

- CCS CfDs need to accommodate the risk sharing needs of early projects and enable the transition of the technology from the arrangements established under the CCS competition to enduring arrangements that will be maintained once the technology is fully matured.
- There needs to be transparent structuring, composition and design of CfDs, so that returns on investment are clear and not subject to change.
- There needs to be transparency over the continued availability of funding for CCS CfDs within the constraints of the Levy Control Framework.

7.4 A strategic approach to infrastructure development and sharing (pipeline and storage)

It is now widely accepted that a CO2 transport network supplying common storage hubs is the most cost-effective approach to CCS deployment, subject to timely rollout of individual projects to ensure that the 'right-sized infrastructure reaches full utilisation.[69,70] For example, by doubling the investment in a pipeline, the pipeline diameter can be increased to carry 10 times the CO2 capacity.

[68] Carbon Capture and Storage Association Response to Energy and Climate Change Committee Inquiry into Carbon Capture and Storage, Sept 2013.
[69] Element Energy, Developing a CCS network in the Tees Valley Region, Final Report for One North East and NEPIC, December 2010.
[70] CCS Cost Reduction Taskforce, The Potential For Reducing The Costs of CCS in The UK, Final Report, May 2013.

Development of an optimal network will require a long term vision for infrastructure planning and build. A well-designed pipeline network will allow new capture and storage sites to join over time. It will also be optimised to ensure maximum utilisation over the assets lifetime, whilst minimising distance travelled, and the need for expensive additional new build and associated planning costs. This means that the location of current and future power generation plant, as well as potential clusters of large industry carbon emitters has to be taken into account.

A transport and storage network is particularly vital in enabling the cost-effective decarbonisation of industrial sectors, as their cost of development would be entirely prohibitive to the majority of individual plants.

The cluster approach not only reduces capital and operational costs, it also increases the reliability of storage service by allowing operational switching between storage sites when necessary.

7.5 Appropriate support for industry CCS

Industry CCS projects will not benefit from power generation support mechanisms such as CfDs, and there are currently no specific policies in place to incentivise investment in the technology. The recent acknowledgement of need for specific policies for industrial CCS in the Heat Strategy has been welcomed, but is unlikely to catalyse sufficiently rapid action.

The benefits associated with industrial CCS have been clearly defined (Section 5) and these sectors urgently need capital support and market mechanisms to kick start early investment, and ensure parallel, not sequential development with the power sector. The deployment of CCS in industrial sectors is particularly urgent as many of these sectors are facing difficult decisions regarding their continued operation in a carbon constrained world, and if cost-effective CCS is not available as a decarbonisation option, these sectors will likely re-locate to other countries. This would have severe impacts on the UK economy.

In particular, given the need to adapt capture technologies to meet specific plant characteristics, early demonstration is essential in providing real time data to improve performance and reduce risk. Without this, there is little chance that industrial sector CCS in the UK will play its part in carbon emissions reduction during the 2020s.

Lastly, clear alignment of Energy Policy (i.e. CCS deployment) with Industry Policy will help secure investment by the industrial sector. This should include:

- A united approach to CCS within the forthcoming Industrial Roadmaps. Broader industrial policy is a key factor influencing whether companies invest in new and more efficient plant.[71]
- Clear acknowledgement of the role of energy pricing in maintaining EIIs within the UK.
- Support for development of CO2 Enhanced Oil Recovery.
- An appropriate incentive framework to deal with issues of international competitiveness (for example a capital fund or FiT mechanism to reward process carbon captured), since most of the need for CCS in industrial applications will be in trade-exposed sectors.

[71] TUC, *Building our low-carbon industries*: the benefits of securing the energy-intensive industries in the UK, June 2012.