DEPARTMENT OF ENERGY & CLIMATE CHANGE

CCS Roadmap

Supporting deployment of Carbon Capture and Storage in the UK

April 2012


DEPARTMENT OF
ENERGY
&CLIMATECHANGE

Contents

Ministerial foreword

Around the world, governments and businesses are faced with a difficult dilemma. In less than a decade, we must halt the rise in global carbon dioxide emissions. In the decades to come, emissions must fall – while delivering more energy and more growth to a world hungry for both.

Carbon Capture and Storage (CCS) will play a vital role in helping us resolve this dilemma. CCS is the only technology that can turn high carbon fuels into genuinely low carbon electricity. It is essential if we are to meet the challenge of climate change whilst maintaining security of energy supplies.

Renewable technologies, new nuclear power plants and energy efficiency will all play their part. But if we are to balance supply and demand – and make sure our energy grids can cope with increasing amounts of intermittency – we will still need fossil fuels.

According to the International Energy Agency, CCS will play a vital role in worldwide efforts to limit global warming, delivering a fifth of the emissions reductions needed by 2050. To keep to that trajectory, more than 3,000 CCS projects must be up and running by 2050.

Developing CCS is a significant undertaking; one that must be replicated around the world. The technology has not yet been deployed at commercial scale. But in this difficulty lies real opportunity – not just for the Government, as we strive to meet our ambitious carbon targets, but also for UK businesses. CCS is a technology of global importance; we have a chance to stake our claim on it.

This Roadmap is about a shared challenge for Government, industry and the wider CCS community in the UK. That challenge is to create the right market conditions to deploy technology that can contribute so much to the battle against climate change. For if CCS it is to have a future, we must demonstrate that it can compete with other low carbon technologies.

Following the decision not to proceed with the project at Longannet, we now know a great deal more about what it takes to make a CCS project work. That vital knowledge has been widely shared thanks to our decision to publish the Front End Engineering and Design studies for the Longannet and Kingsnorth projects.

The Government remains steadfast in its commitment: we will work with industry to make CCS a reality.

We have made £1 billion available to support the capital expenditure of early CCS projects; the European Commission is working through the process of allocating funding from the New Entrant Reserve; and we are putting in place the building blocks for a low carbon electricity market in which CCS can play a full part.

We want CCS to succeed. But it will only be part of the future energy mix if it can be cost-competitive with other low carbon technologies, preventing excess costs to consumers. That is why our CCS programme – and this Roadmap – is focused on identifying cost reductions, and then realising them.

Our aim is to enable industry to take investment decisions to build CCS equipped fossil fuel power stations in the early 2020s. That will only be achieved by working in partnership.

As part of our commitment to achieving that aim, we will:

- Create an electricity market that will enable CCS to compete with other low carbon sources;
- Launch a CCS commercialisation programme with £1bn of capital support;
- Work closely with industry to reduce costs, including through the establishment of a CCS Cost Reduction Task Force;
- Remove barriers and obstacles to deployment;
- Develop the regulatory environment, including for the long-term storage of CO_2;
- Promote the capture and sharing of knowledge to accelerate deployment; and
- Help build a stable foundation by supporting private sector access to skills and developing the supply chain.

This Roadmap sets out our programme in more detail, and I look forward to reviewing progress regularly with the CCS Development Forum.

We have come a long way; but there remains much more to be done. By working together, we can take advantage of this unique opportunity – and turn CCS from an exciting possibility into a commercial reality.

Edward Davey
Secretary of State for Energy and Climate Change

Executive summary

Tackling climate change requires global action and every country needs to play its part. For the UK this will mean a transformation in the way we generate and use energy – a long-term transition to secure, affordable, low carbon energy on the way to an 80% cut in greenhouse gas emissions by 2050.

Carbon Capture and Storage (CCS) has the potential to be one of the most cost effective technologies for decarbonisation of the UK's power and industrial sectors, as well as those of economies worldwide. CCS can remove carbon dioxide (CO_2) emissions created by the combustion of fossil fuels in power stations and in a variety of industrial processes and transport it for safe permanent storage deep underground, for example deep under the North and Irish Seas. Modelling for the Carbon Plan[1] shows that CCS can play a significant role in achieving decarbonisation of the UK economy at least cost. In the power sector CCS will contribute to diversity and security of electricity supply, and also has a unique role in providing a continuing role for flexible fossil fuel capacity that is able to respond to demand in the way that other low carbon technologies are not able to.

CCS also represents a major green growth opportunity for the UK. Worldwide up to $40 billion has been committed by Governments to support CCS projects[2] and, if CCS opportunities develop as anticipated, benefits for UK-based firms have been estimated to be between £3 - 6.5 billion a year by the late 2020s[3]. The deployment of CCS is at an early stage, so to the extent that UK based business can take advantage of these local opportunities it should help to establish them as leaders in a developing worldwide market.

The Government is committed to helping make CCS a viable option for reducing emissions in the UK and in doing so to accelerate the potential for CCS to be deployed in other countries. Our vision is for widespread deployment of cost-competitive CCS. We are seeking to support the development of a sustainable CCS industry that will capture emissions from clusters of power and industrial plants linked together by a pipeline network transporting CO_2 to suitable storage sites offshore. That CO_2 might also be used to recover additional amounts of the UK's hydrocarbon reserves, thereby improving the economics of CCS and accelerating deployment. We will support the development of a strong and robust supply chain in the UK, creating jobs and markets locally and nationally to serve the early CCS plant and later clusters of CCS activity. Playing to the UK's business strengths and encouraging projects clustering in regions reflects the Government's ambition to capture opportunities for 'green jobs' that will arise from an emerging market for CCS.

To make this vision a reality we must invest now. This Roadmap sets out how we will achieve our goal of seeing commercial deployment of CCS in the UK in the 2020s.

---

[1] DECC, 2011. The Carbon Plan. http://www.decc.gov.uk/en/content/cms/tackling/carbon_plan/carbon_plan.aspx.

[2] GCCSI, 2011. The Global Status of CCS: 2010. http://www.globalccsinstitute.com/publications/global-status-ccs-2010.

[3] AEA, 2010. Future Value of Carbon Abatement Technologies in Coal and Gas Power Generation to UK Industry. http://www.decc.gov.uk/assets/decc/What%20we%20do/UK%20energy%20supply/Energy%20mix/Carbon%20capture%20and%20storage/1_20100629105946_e_@@_futurevalueCATUKindustry.pdf.

The UK has a number of key advantages that make this country ideally suited for the deployment of CCS, including:

- Extensive storage capacity under the UK seabed, particularly under the North Sea;
- Existing clusters of power and industrial plants with the potential to share CCS infrastructure;
- Expertise in the offshore oil and gas industry which can be transferred to the business of CO_2 storage; and
- Academic excellence in CCS research.

To ensure CCS can contribute to the UK's low carbon future, the Government is taking forward a programme of interventions that aim to make the technology cost-competitive and enable the private sector to invest in CCS equipped fossil fuel power stations, in the 2020s, without Government capital subsidy. Development of cost-competitive CCS will mean that low carbon fossil fuel power stations and industrial plant can be widely deployed in the UK in the 2020s and beyond helping this country to meet ambitious carbon reduction targets at lowest cost to consumers whilst maintaining diversity and security of energy supplies.

Achieving this ambition is a shared challenge for Government and industry. If the ambition is met, then the opportunity to roll out low carbon fossil fuel power stations at scale will develop. Government can provide support – including financial support – and address risk and remove barriers in pursuit of this outcome, but it is industry that has the technical and commercial expertise needed to move CCS toward deployment.

We intend to focus first on development of CCS for the power sector because it is the largest source of emissions in the UK, but CCS on industrial plant will also be important for meeting emissions reduction targets. Early deployment on power stations could be the starting point for the development of CCS clusters with multiple sources of CO_2, including industrial sources, benefitting from access to shared transport and storage infrastructure.

There are three key challenges which the Government believes must be tackled to enable commercial deployment of CCS in the UK:

- **Reducing the costs and risks** associated with CCS so that it is cost-competitive with other low carbon technologies;
- **Putting in place the market frameworks** that will enable CCS to be deployed by the private sector cost effectively; and
- **Removing key barriers** to the deployment of CCS.

To address these challenges the Government is taking forward a programme of interventions which is one of the most comprehensive offered by any country in the world to support the development of CCS. The programme includes:

- **A CCS Commercialisation Programme with £1 billion in capital funding** to support commercial-scale CCS, targeted specifically to learn by doing and to share

resulting knowledge to reduce the cost of CCS such that it can be commercially deployed in the 2020s;

- **A £125m, 4-year, co-ordinated R&D and innovation programme**[4] covering fundamental research and understanding, through to component development and pilot-scale testing, to ensure that the best ideas – with a clear focus on cost reduction – can be taken forward to the market, and **establishing a new UK CCS Research Centre**;

- **Development of a market for low carbon electricity** through Electricity Market Reform (EMR), including availability of Feed-in Tariff Contracts for Difference for low carbon electricity tailored to the needs of CCS equipped fossil fuel power stations;

- **Intervention to address key barriers to the deployment of CCS** including work to support the CCS supply chain, develop transport and storage networks, prepare for the deployment of CCS on industrial applications and ensure the right regulatory framework is in place; and

- **International engagement** focused on sharing the knowledge we have generated through our programme and learning from other projects around the world to help accelerate cost reduction.

Figure 1. The five key interventions Government is undertaking to help deliver cost-competitive CCS in the 2020s.

[4] The programme includes a £20 million innovation competition launched on 13 March 2012. http://www.decc.gov.uk/en/content/cms/emissions/ccs/innovation/inn_comp/inn_comp.aspx

Given the critical importance attached to the reduction of costs, the Government is asking industry to establish a CCS Cost Reduction Task Force to work alongside the OCCS to set out a path and action plan to reduce the costs of CCS. The Task Force will identify potential reductions in the cost of deploying the technology; the scale of those reductions; and the actions required to deliver them. The Task Force will report to the UK Government's CCS Development Forum[5] setting out its findings and recommendations for action by Government and industry. To support the Task Force DECC has commissioned a study into the costs of CCS and potential for cost reduction which we will shortly be publishing.

This Roadmap sets out the strategic context for the Government's interventions to support the development and deployment of cost-competitive CCS and the steps being taken to achieve this outcome. The Roadmap consists of a summary strategy document, an action plan and a series of supporting documents published on DECC's website which give more detail on specific aspects of the Government's interventions. The Roadmap will inform the Government's dialogue with industry on the actions taken to deliver cost-competitive CCS and will be reviewed accordingly. The action plan will be reviewed through the CCS Development Forum and updated as appropriate.

The Office of Carbon Capture and Storage

The Office of Carbon Capture and Storage (OCCS), within the UK Department of Energy and Climate Change, was created to help drive delivery of the Government's climate and energy objectives. The OCCS sets the strategic path for the development and wide-scale deployment of CCS in the UK. Among other things, it was established to create the policy and support arrangements to stimulate private sector investment in CCS; to work to maximise the global opportunities for UK businesses and the economy to benefit in the form of jobs and wealth creation; and to collaborate with stakeholders to remove barriers to investment and development in the UK and globally. Above all the OCCS aims to implement measures to help drive down the cost of CCS so it can be cost-competitive with other low carbon generation alternatives.

[5] Further information about the CCS Development Forum can be found on the DECC website at: http://www.decc.gov.uk/en/content/cms/emissions/ccs/stakeholder/stakeholder.aspx

1. Government's commitment to CCS

1.1. The Government is committed to making CCS a viable option as part of our low carbon generation mix and to facilitating development of CCS as a key technology for the decarbonisation of the industrial sector.

1.2. ***Our vision*** is for a future with widespread deployment of cost-competitive CCS, with tens of GWs of installed capacity in the power sector and CCS on a variety of industrial applications. In such a world it might be expected that there would be clusters of power and industrial plants linked together by a pipeline network transporting CO_2 to suitable clusters of storage sites offshore. The potential for such clusters already exists in several regions in the UK, including the east coast of Scotland, Yorkshire & Humber, Teesside, and around the East Irish Sea, where there are large concentrations of industry close to potential storage capacity. There are also other smaller clusters and other potential storage sites to be utilised, which would also require supporting infrastructure to be installed. The CCS Commercialisation Programme will consider projects which stimulate the development of these clusters where to do so could be beneficial to achieving the Programme objectives, is affordable and represents value for money.

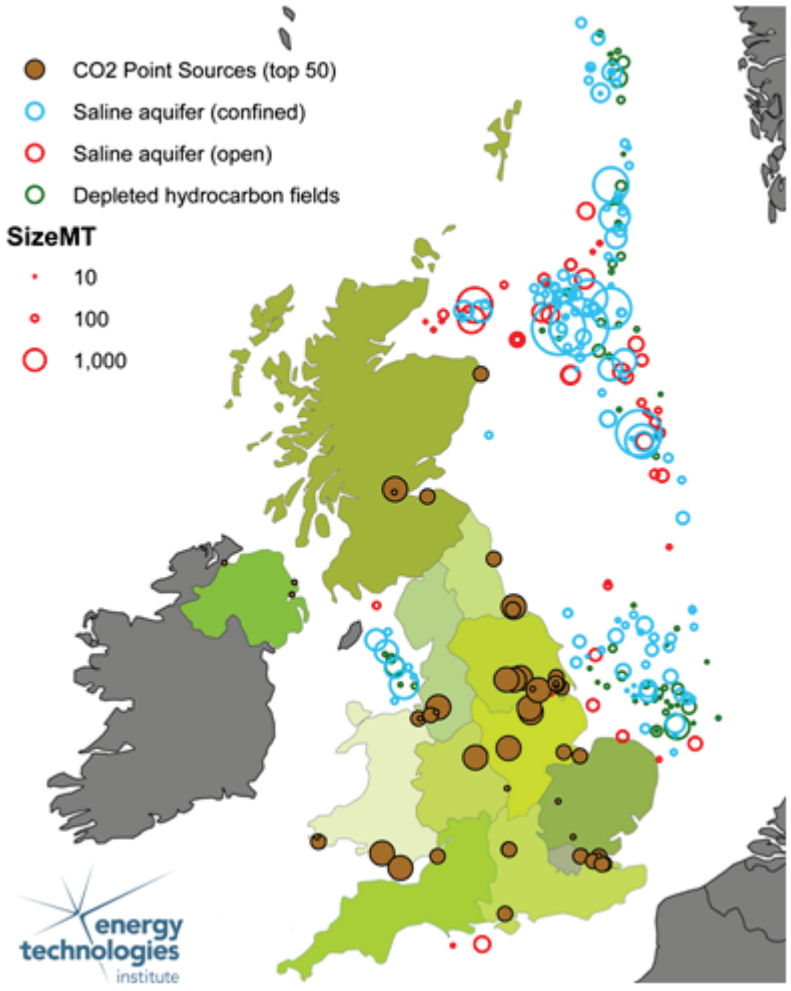


Figure 2. Proximity of the UK's largest industrial emitters to CO_2 storage sites in the North and Irish Seas. Map provided by the Energy Technologies Institute.

1.3. If large volumes of CO_2 become available in the North Sea they could be used for enhanced hydrocarbon recovery[6], improving the economics of the whole CCS chain – turning CO_2 into a valuable commodity rather than a costly liability, making better use of the country's hydrocarbon reserves and helping to accelerate deployment of CCS.

1.4. To make this vision a reality we must invest now. This Roadmap sets out the steps the Government will take to help facilitate the commercial deployment of CCS in the UK in the 2020s.

1.5. ***Our focus*** is on reducing the costs and risks associated with CCS so that it can be deployed cost-competitively in the 2020s alongside other low carbon technologies and approaches.

1.6. There are three key challenges which the Government believes must be tackled to enable commercial deployment of CCS in the UK:

- **Reducing the costs and risks** associated with CCS so that it is cost-competitive with other low carbon technologies;
- Putting in place the **market frameworks** that will enable CCS to be deployed by the private sector cost effectively; and
- **Removing key barriers** to the deployment of CCS for both the power and industrial sectors.

1.7. The UK is a world-leader on the development of CCS and we have already done much to address these challenges. This includes implementing the world's first regulatory and commercial framework for the storage of CO_2 and supporting Front End Engineering and Design (FEED) studies at Longannet and Kingsnorth. These studies showed that commercial-scale CCS is technically feasible. The Government made the complete engineering designs for the end to end chain of capture, transport and storage freely available to support the worldwide development of the technology[7].

1.8. However, there is much more to do. The Government is taking forward a programme of interventions which we believe is one of the most comprehensive packages offered by any country in the world to support the development of CCS.

[6] Enhanced hydrocarbon recovery or EHR is the use of CO_2 to increase the volume of oil or gas that can be extracted from an oil or gas field.

[7] Further information about the FEED studies can be found on the DECC website at: http://www.decc.gov.uk/en/content/cms/emissions/ccs/demo_prog/feed/feed.aspx

The Scottish Government's commitment to CCS

The Scottish Government supports CCS as a critical new technology that would transform the way we generate power, help reduce carbon emissions and ensure security of supply. Alongside the accelerated expansion of renewables, the electricity mix must benefit from clean fossil fuel technologies. In anticipation of several large-scale CCS projects coming forward in Scotland the Scottish Government have taken forward a range of research studies, regulatory, licensing and permitting pre-work in order to lay the foundations for the legislation necessary for processing project applications for full-chain CCS in Scotland.

The Scottish Government is committed to Scotland achieving its full potential in energy generation and supply. In May 2009, the First Minister established the Scottish Energy Advisory Board (SEAB) for high-level, effective, open and informed engagement between Ministers, the energy industry and other relevant bodies on the main challenges facing the energy sector in Scotland. The Thermal Generation and CCS Industry Advisory Group is a themed workstream of the SEAB and meets quarterly to explore all aspects of information and action required in order to support the delivery of CCS.

Scotland is well-placed in the development and commercialisation of CCS with a strong knowledge base and the expertise in our universities and industry, the infrastructure and storage capacity in the North Sea.

The Scottish Government continues to fund research studies and papers on the subject of CCS. The Scottish Carbon Capture and Storage organisation (SCCS) based in Edinburgh is one of the largest CCS research groupings in the UK comprising in excess of 65 researchers, unique in their connected strength across the full CCS chain. New business development officers recently funded by the Scottish Funding Council/ Scottish Government funding package for SCCS (Edinburgh, Heriot Watt and British Geological Survey) are now in place which will assist in further establishing the high value contribution this centre offers in making CCS a reality.

2. Why we need CCS

2.1. Carbon Capture and Storage (CCS) is a process to capture carbon dioxide (CO_2) that would otherwise be emitted to the atmosphere by large point sources, such as fossil fuel power stations, and permanently store the CO_2 deep underground. CCS enables the continued use of fossil fuels in power generation and some industrial processes without the damaging effects of the resulting CO_2 emissions on the climate. It is anticipated that around 90% of the CO_2 emitted from these large point sources could be captured and safely stored.

2.2. More information on CCS can be found on the DECC website at: http://www.decc.gov.uk/en/content/cms/emissions/ccs/what_is/what_is.aspx.

The international context

2.3. There is overwhelming scientific consensus that emission of man-made CO_2 to the atmosphere is a major contributor to climate change[8]. The need to reduce emissions of CO_2 and other greenhouse gases is recognised by the Government in the Climate Change Act of 2008, which sets legally binding targets for the UK to reduce emissions of CO_2 and other greenhouse gases by 80% from 1990 levels, by 2050. The EU has similarly set a target for the reduction of CO_2 and other greenhouse gases by 20% from 1990 levels, by 2020 and through the UNFCCC process we are pressing for the creation of a legally binding framework that commits all countries to keeping their emissions of greenhouse gases below agreed limits.

2.4. CCS is a key technology in the fight against dangerous climate change and will be instrumental in helping governments to deliver ambitious international action. Many of the world's major economies such as the US, India and China are heavily dependent on fossil fuels and their continued use is inevitable. Studies undertaken by the International Energy Agency (IEA) on behalf of the G8 have concluded that, to achieve a 50% reduction in carbon emissions by 2050 cost effectively, CCS will be needed to deliver about a fifth of this target. Without CCS the delivery cost of meeting a 50% global reduction target by 2050 will be 70% higher[9][10]. The latest IEA estimates show that globally energy-related CO_2 emissions in 2010 were the highest in history, with 44% coming from coal combustion[11]. With an estimated 80% of projected emissions in 2020 locked-in because emissions intensive plant are already in place or under construction, it is essential that CCS technologies are developed for application to new build and existing infrastructure.

---

[8] IPCC, 2007. Fourth Assessment Report: Climate Change 2007. http://www.ipcc.ch/publications_and_data/publications_and_data_reports.shtml.

[9] A 50% reduction in greenhouse gas emissions is consistent with a strategy to limit the long-term global temperature rise to an average of 2°C to 3°C.

[10] IEA, 2009. Technology Roadmap: Carbon Capture and Storage. http://www.iea.org/papers/2009/CCS_Roadmap.pdf.

[11] IEA, 2011. http://www.iea.org/index_info.asp?id=1959.

International engagement

On a least cost basis, the IEA estimate that CCS will deliver 19% of the global reduction in CO_2 emissions that is required by 2050 if we are to limit global warming to a maximum of two degrees. Achieving this goal will necessitate the construction of 3400 plants worldwide with over 2000 of these being built in developing countries. Constraints on public finances in many countries have resulted in delay and cancellation of a number of major projects and it is therefore essential that we strengthen the CCS community in order to maximise the benefits of shared learning and minimise duplication and financial waste. At the heart of the UK's international strategy is a desire to use the work being done here in the UK to drive ambition elsewhere and to learn from progress on CCS elsewhere to support deployment in the UK.

In order to address challenges to the global deployment of CCS, the UK supports a range of bilateral, multilateral and regional workstreams. These seek to address both practical and political challenges. We have worked bilaterally with partners in China, South Africa and elsewhere to provide evidence of the strategic relevance of CCS to meeting carbon reduction goals and identified where future work is needed to address local barriers. We are supporting research and development activities through the UK Research Councils and through our membership of, for example, the International Energy Agency's Greenhouse Gas R&D Programme. Further we are supporting efforts to increase capacity in developing countries through, for example, the support provided to the Carbon Sequestration Leadership Forum's Capacity Building fund.

We are also actively seeking to ensure CCS remains a topic for Ministerial discussion and engagement. We established, with Australia, the Carbon Capture Utilisation and Storage initiative which reports to the Clean Energy Ministerial (CEM) and are working with like-minded countries and industrial partners to ensure CCS remains a priority for action not only here in the UK but also abroad. We particularly welcome the decision made in Durban in November 2011 to allow CCS projects to be considered for financial support from the Clean Development Mechanism.

The CEM is a high-level global forum to promote policies and programmes that advance clean energy technology, to share lessons learned and best practices, and to encourage the transition to a global clean energy economy. Initiatives are based on areas of common interest among participating governments and other stakeholders.

Ministers from more than 20 participating countries gather to discuss progress made by the 11 CEM clean energy initiatives, explore ways to enhance collaboration between participating governments, and develop strategies to drive public-private engagement to support clean energy deployment.

The Carbon Capture, Use and Storage Action Group, led by the governments of Australia and the UK, is working to help member countries that have endorsed the 8 recommended actions on CCS to deliver progress.

For further information: http://www.cleanenergyministerial.org/events/cem3/index.html

Why the UK, why now?

2.5. Development and deployment of CCS is key if the UK is to achieve our climate change targets whilst maintaining a vibrant, competitive economy. We are geographically well-placed to take forward CCS in the UK having well understood sedimentary basins suitable for storage in our territorial waters close to clusters of industrial emitters along our coastlines. According to a recent study by the Energy Technologies Institute the technical CO_2 storage capacity of the UK and our continental shelf could be up to ~70 billion tonnes – which would be sufficient to store 100 years worth of current emissions from the energy sector.

2.6. The power sector is the single largest source of UK emissions today, accounting for 27% of emissions – 157 $MtCO_2e$ – in 2010[12]. By 2050 emissions from the power sector need to be close to zero if we are to meet our legally binding target to reduce UK greenhouse gas emissions to 80% of 1990 levels. During the 2020s, deep cuts in emissions from the power sector will be needed to keep us on a cost effective path to the 2050 target. In 2010, fossil fuels were used for 72% of the UK's electricity generation. CCS technology is currently the only means by which fossil fuels can be maintained within the UK generation mix, whilst meeting our 2050 carbon targets.

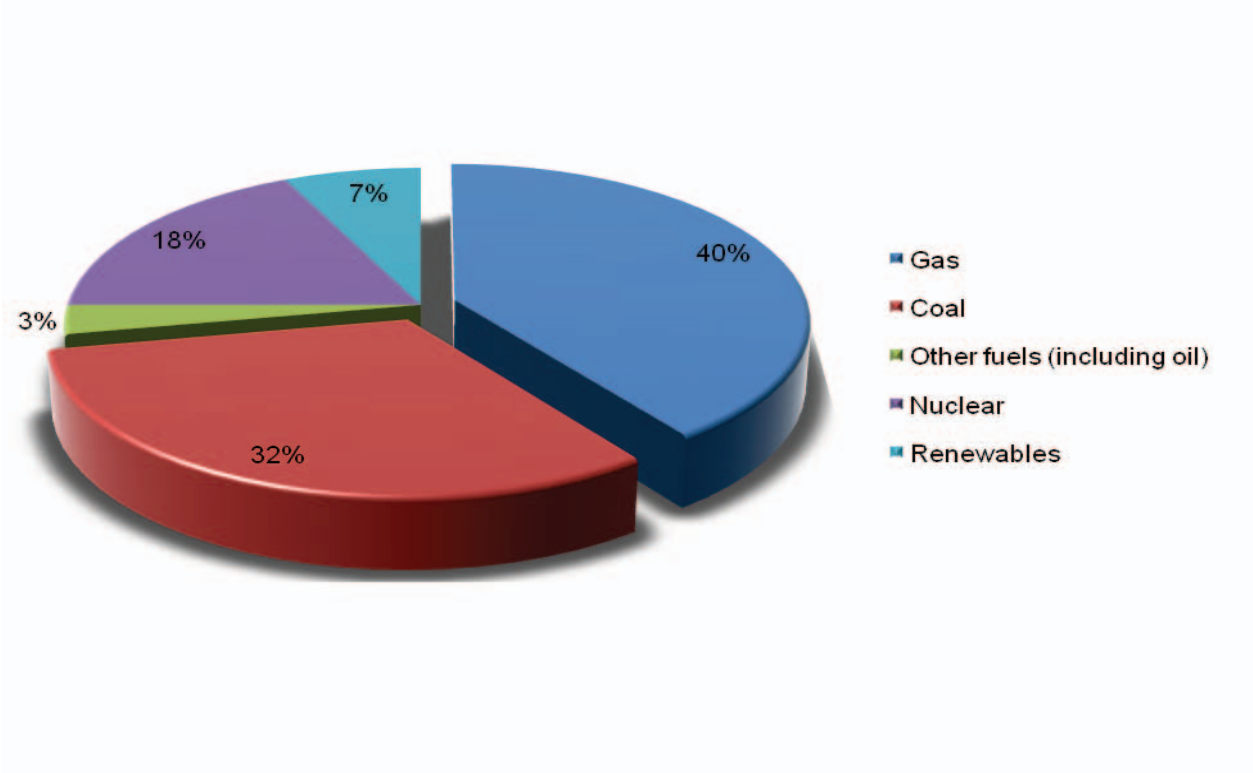


Figure 3. Fuel used for UK electricity generation in 2010[13]

[12] DECC, 2011. UK emissions statistics, 2010 final UK figures. http://www.decc.gov.uk/en/content/cms/statistics/climate_stats/gg_emissions/uk_emissions/2010_final/2010_final.aspx.

[13] DUKES 2011, Table 5.4. http://www.decc.gov.uk/en/content/cms/statistics/energy_stats/source/electricity/electricity.aspx.

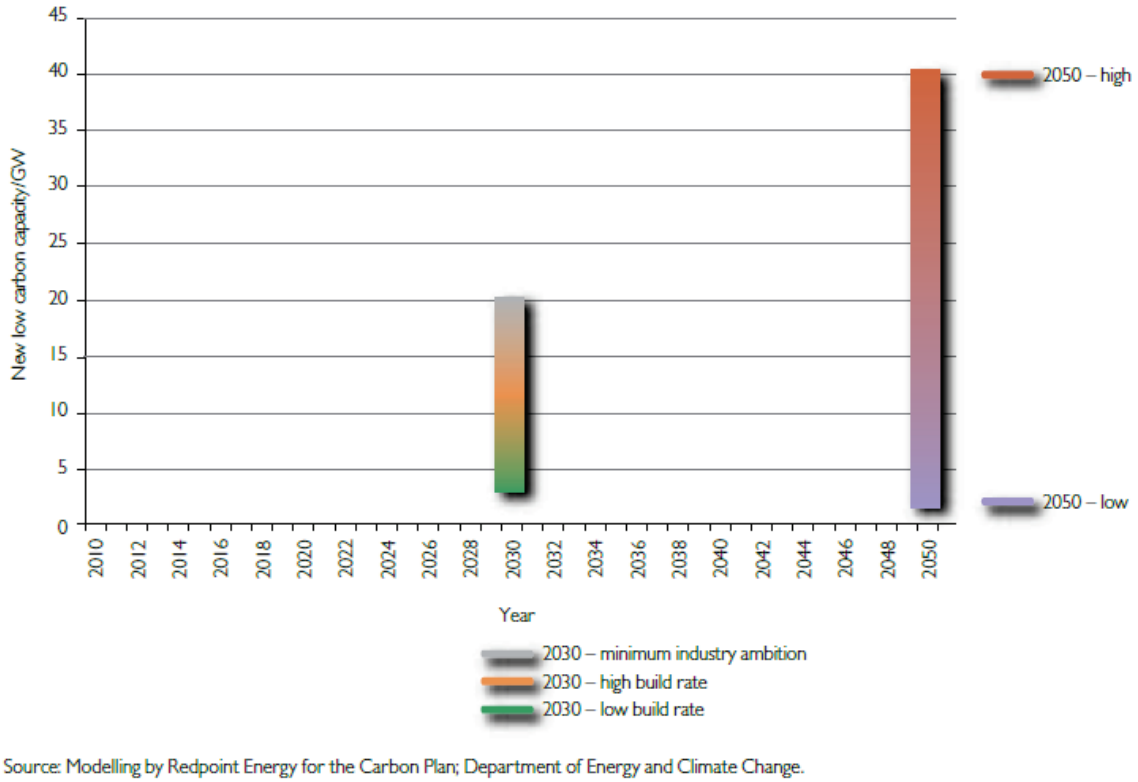
2.7. There are many different ways to achieve decarbonisation of the power sector. Government policy is not to dictate this mix, but to allow technologies to compete to ensure the overall system is delivered at the lowest possible cost to the bill payer. We can nevertheless produce projections using the best evidence currently available. The scenarios modelled for the Carbon Plan[14] suggest that around 40 - 70 GW of new low carbon electricity generating capacity will be needed by 2030, and depending on demand and the mix of generation that is built, CCS could contribute as much as 10 GW by 2030 and up to 40 GW by 2050. The CCS Association, the representative body for the CCS industry, have set out their ambition for 20 - 30 GW of CCS to be deployed by 2030[15]. The measures being taken by Government, as set out in this Roadmap, should enable this ambition to be achieved, subject to CCS demonstrating its effectiveness as a cost-competitive low carbon source of electricity generation in time to meet projected demand.

2.8. Current cost estimates suggest that the levelised cost of electricity from CCS equipped fossil fuel plants may be higher than from nuclear plants but cheaper than from some renewable sources, such as offshore wind farms. CCS also has the potential to increase the total amount of low carbon capacity on the system given build constraints and inherent risks to deployment of other technologies, to add diversity and security of supply, and to reduce costs in a scenario with low fossil fuel prices and high nuclear costs. It also has a unique role in providing a significant level of capacity that is able to respond to demand in the way that nuclear and wind (the main source of UK renewables) are not able to. Since electricity supply has to match demand at all times a balanced system must be able to respond to demand in this way.

2.9. It is also essential that Government and industry develop a range of low carbon technologies to insure against the risk of one or more technologies being more expensive than current estimates suggest or becoming publicly unacceptable. The Committee on Climate Change have also concluded that new low carbon capacity would need to consist of a mixture of nuclear, renewables and CCS[16].

2.10. In the longer-term, CCS fitted to biomass power stations is the only low carbon technology that could offer the opportunity to permanently remove CO_2 from the atmosphere. Bioenergy carbon capture and storage (BE-CCS) could produce bioenergy in the form of electricity, hydrogen, heat and aviation fuels, but most significantly permanently store underground the CO_2 from these processes that was taken from the atmosphere by plant growth, providing net carbon removal from the atmosphere or 'negative emissions'. These negative emissions could then be used to offset emissions from other harder to decarbonise sectors. This makes CCS and BE-CCS an exceptionally valuable technological option. This view was strongly supported in the recent bioenergy review by the Committee on Climate Change[17].

[14] DECC, 2011. The Carbon Plan. http://www.decc.gov.uk/en/content/cms/tackling/carbon_plan/carbon_plan.aspx.
[15] CCSA, 2011. A Strategy for CCS in the UK and Beyond. http://www.ccsassociation.org/press-centre/reports-and-publications/.
[16] Committee on Climate Change, www.theccc.org.uk.
[17] Committee on Climate Change, 2011. Bioenergy Review. http://www.theccc.org.uk/reports/bioenergy-review.



Source: Modelling by Redpoint Energy for the Carbon Plan; Department of Energy and Climate Change.

Figure 4. Scenarios for CCS capacity in the UK power sector to 2050

2.11. In the industrial sector CCS has an essential role to play capturing emissions. In particular CCS will be critical to reducing emissions from production of industrial heat, for example from the continued use of coke-fired blast furnaces for steel production. For some industrial processes CO_2 emissions are intrinsic and can only be mitigated through abatement options such as CCS.

2.12. CCS also represents a major ***green growth*** opportunity for the UK. Worldwide up to $40 billion has been committed by Governments to support CCS projects[18] and, if CCS opportunities develop as anticipated, export opportunities for UK based firms have been estimated to be between £3 - 6.5 billion a year by the late 2020s[19]. The deployment of CCS is at an early stage, so to the extent that UK based business can take advantage of these local opportunities it should help to establish them as leaders in a developing worldwide market. Analysis previously commissioned by DECC[20] highlighted areas of UK strength in procurement and manufacturing, engineering design, project management,

[18] GCCSI, 2011. The Global Status of CCS: 2010. http://www.globalccsinstitute.com/publications/global-status-ccs-2010.

[19] AEA, 2010. Future Value of Carbon Abatement Technologies in Coal and Gas Power Generation to UK Industry. http://www.decc.gov.uk/assets/decc/What%20we%20do/UK%20energy%20supply/Energy%20mix/Carbon%20capture%20and%20storage/1_20100629105946_e_@@_futurevalueCATUKindustry.pdf.

[20] Technopolis, 2010. A Study to Explore the Potential for CCS Business Clusters in the UK. http://www.decc.gov.uk/assets/decc/What%20we%20do/UK%20energy%20supply/Energy%20mix/Carbon%20capture%20and%20storage/1_20100317095408_e_@@_ccsbusinessclusters.pdf.

construction, financial and legal, and commissioning. The UK has world-class engineering capability within the power sector and the UK is well represented in some manufacturing sectors likely to be important for CCS, including large-scale compressors, pipelines and air separation plants. In the long-term there is the possibility for UK based high-value manufacturing operations to emerge to service the EU and global markets. We intend to work with the industry throughout the supply chain to make the most of this opportunity and this work is covered in the Skills and supply chain section at chapter 6.

2050 Pathways Calculator

The DECC 2050 Futures published in the Carbon Plan were informed by the 2050 Pathways Analysis.

The 2050 Pathways work presents a framework through which to consider choices and tradeoffs including the role CCS might play in ensuring secure, low carbon energy and the 2050 Calculator provides a detailed look at the UK's energy and emissions system.

My2050 is a web based counterpart designed to help the public understand the choices and the role CCS and other measures might play in moving to a secure low carbon economy.

http://www.decc.gov.uk/en/content/cms/tackling/2050/2050.aspx.

3. Understanding the challenge: how to enable cost-competitive CCS

We are:

- **Intending to publish a study identifying and estimating potential CCS cost reductions**
- **Asking an industry led CCS Cost Reduction Task Force to set out an industry view of what needs to be done to make CCS cost-competitive with other low carbon technologies** – building on the study and other evidence the Task Force will set out findings and make recommendations for further action to realise reductions in the cost of CCS
- **Working with other leading Governments, the Global Carbon Capture and Storage Institute and the European Commission** to ensure that knowledge and lessons learned in the UK and overseas are shared to inform a best practice approach
- **Focusing the other actions in this Roadmap, including the new CCS Commercialisation Programme, on reducing the cost of CCS to ensure that it is commercially deployable in the early 2020s**
- **Working with the industrial sector to identify the current state of innovation on CCS and the potential for Government interventions to enable deployment**
- **Working with the industrial sector to identify the barriers and opportunities to industrial CCS and the potential role for Government**

3.1. We want CCS to work and to play a major part in the future UK electricity mix, but the deployment of CCS is not an end in itself. It will only be part of the mix if its potential as a low carbon, flexible source of cost-competitive electricity can be demonstrated in practice.

3.2. Analysis conducted to date suggests that this is achievable. Our best estimate using currently available data from studies conducted by Mott MacDonald[21], PB Power[22] and Arup[23] for DECC shows that by the 2020s electricity generated from fossil fuel plants with CCS is expected to be more expensive than electricity generated from baseload nuclear

[21] Mott MacDonald, 2010. Electricity Generation Cost Model.
[22] Parsons Brinckerhoff, 2011. Electricity Generation Cost Model.
[23] Arup, 2011. Review of the generation costs and deployment potential of renewable electricity technologies in the UK.
All three of these reports are available from the DECC website at:
http://www.decc.gov.uk/en/content/cms/about/ec_social_res/analytic_projs/gen_costs/gen_costs.aspx.

and intermittent onshore wind but competitive with other low carbon generation technologies.

3.3. In the industrial sector studies suggest that CCS has the potential to address up to 38Mt of CO_2 emissions per annum in 2030 (decreasing to 37Mt by 2050) at costs of between £30 and £150 per tonne of CO_2 abated[24]. However, the high upfront capital costs and low overall volumes of CO_2 from individual industrial sites mean that it is unlikely that deployment in the industrial sector will occur prior to the development of power sector projects which will provide the starting point for clusters of projects connected to a shared transport and storage infrastructure.

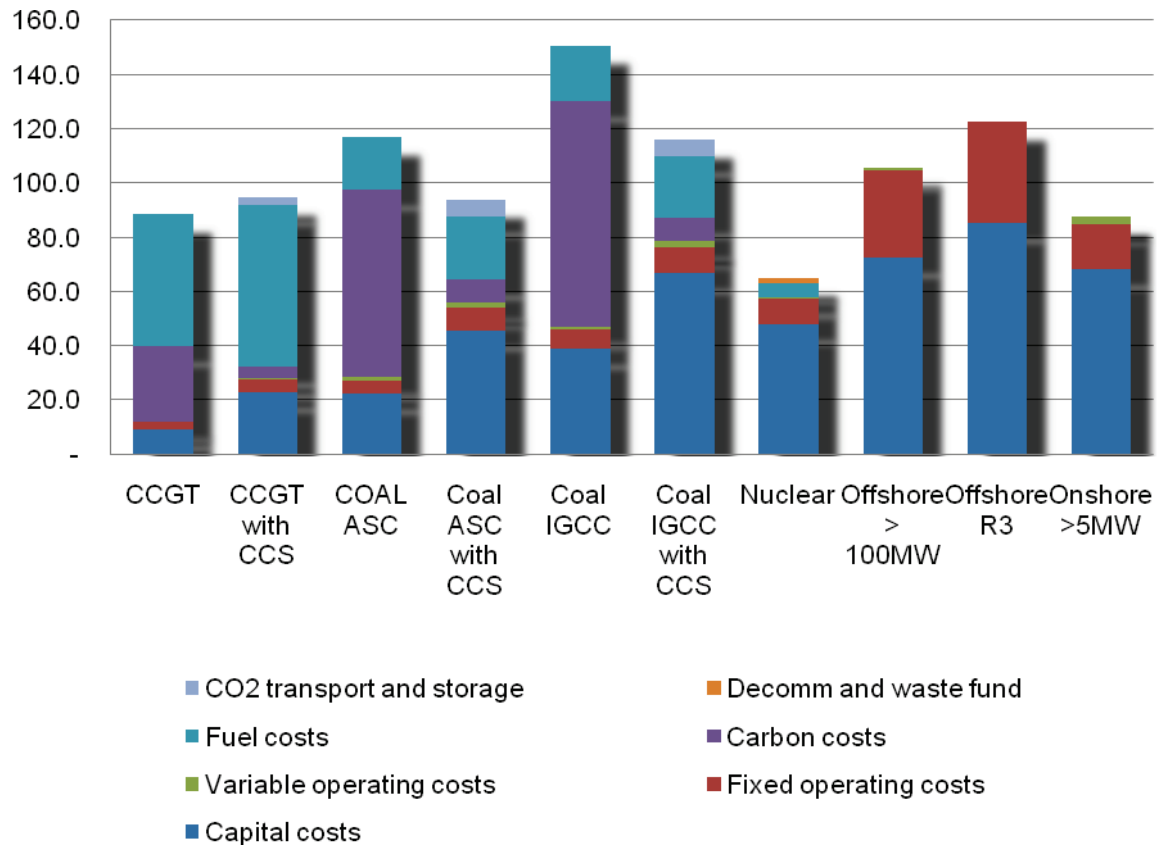


Figure 5. Nth of a kind (NOAK) levelised cost estimates (£s per MWh) for generation technologies for projects starting in 2017[25]

[24] Element Energy for the Committee on Climate Change, 2010. Potential for the application of CCS to UK industry and natural gas power generation. http://downloads.theccc.org.uk.s3.amazonaws.com/0610/pr_supporting_research_element_Energy_CCS_on_gas_and_industry.pdf.

[25] Central estimates of construction, operation, fuel and carbon costs, 10% discount rate. Data from PB Power (2011) and Arup (2011).

3.4. To ensure that we maximise the impact of action by Government and industry it is essential that we understand where effort can be focused to deliver the biggest reductions in cost and risk. While a number of studies have produced analysis in this area, there is a great deal of uncertainty about the costs of CCS, both current and future. DECC has commissioned a study to focus on cost reduction, reviewing existing work and identifying and estimating potential cost reductions that could be realised. The report provides a starting point for the work that Government and industry need to do together to deliver real cost reduction.

Study on the scope for reductions in the cost of CCS

DECC has commissioned a report which analyses the scope for cost reduction by fuel, technology and components for CCS.

Our expectation is that the study will set out ranges of the possible cost reductions in CCS. While these ranges are likely to illustrate the uncertainty in both initial cost estimates and cost trajectory, they are expected to indicate the potential for a downward trend in costs.

The analysis will be compiled from the bottom up, attempting to identify the cost drivers acting on the main components for each of the four main capture technologies, pipelines and the two main storage options. While the report will identify various technical developments it is difficult to translate this into cost changes as more efficient or better performing equipment does not always come at a lower cost. The numbers provided in the report will be the best estimates possible based on available data.

Some examples of areas the report is likely to conclude are worth pursing in order to reduce costs are:

- Compressor advances – energy penalty benefits for all options;
- Air separation advances – energy penalty benefits for oxy combustion and to a lesser extent IGCC;
- Improved solvents and sorbents – resulting in smaller absorbers and lower energy penalties for post combustion;
- Gas recirculation for post combustion gas – reduced absorber size and energy penalties;
- Economies in scale for absorbers – for post combustion;
- Improvements in construction logistics from learning and advanced simulations – for all options;
- Process optimisation for all technology routes; and
- Reduced design margins for all systems.

3.5. Studies can signpost key areas where cost reductions can be found, but studies are not enough. We need industry to use this information to identify and deliver these cost reductions. This partnership between industry and Government is essential if we are to bring forward the deployment of CCS. We are therefore asking industry to establish a CCS Cost Reduction Task Force to work alongside the OCCS to set out a path and action plan to reduce the costs of CCS.

3.6. The objective of the Task Force is to advise Government and industry on reducing the unit cost of CCS so that it can compete with other low carbon technologies in the electricity market by the early 2020s.

3.7. The Task Force will:

- Build on work undertaken for DECC to identify potential reductions in the cost of CCS, the scale of those reductions, and the actions required to deliver those reductions;

- Seek to gain a commitment from industry on initiatives to reduce cost and develop advice setting out the steps industry and Government could take to develop the most promising technologies and establish the right market framework and incentives to encourage industry to invest; and

- Produce a report to the CCS Development Forum setting out its findings and recommendations for action by Government and industry.

3.8. The work of the Task Force will help to shape the future of the Government's CCS interventions. This Roadmap will be updated to reflect the findings and recommendations of the Task Force.

3.9. In the industrial sector we intend to take forward work that will seek to identify the current state of innovation on industrial CCS and the barriers to, and opportunities for, industrial CCS application. This data will provide a better understanding of the problems industrial plants face in using CCS to adapt to a low carbon economy and the role for Government in enabling deployment.

3.10. The UK is not the only country working to ensure that CCS becomes a commercially viable part of our approach to reducing carbon emissions. Countries such as Norway, Canada, Australia and several EU Member States are developing CCS projects and it is vital that we work together to ensure that knowledge is shared and deployment accelerated. Our approach builds on the strong commitment to knowledge sharing from the CCS Commercialisation Programme. It includes engaging through multilateral bodies like the International Energy Agency, Carbon Sequestration Leadership Forum and Clean Energy Ministerial; working with knowledge transfer platforms such as the European CCS Demonstration Project Network and the Global CCS Institute; working with industry representative organisations such as the North Sea Basin Task Force and Zero Emissions Platform; and bilateral engagement with individual countries to support knowledge sharing and collaborative R&D programmes. We will continue to build on this foundation with a clear focus on learning from real projects to accelerate cost reductions in the UK.

4. Realising the vision: enabling commercial CCS

We are:

- **Reforming the electricity market** to enable investment in low carbon power generation
- **Developing long-term contracts (EMR FiT – CfDs) which recognise the potential contribution of CCS to a balanced low carbon electricity system**
- **Exempting power stations with CCS from the Carbon Price Floor** in proportion to the CO_2 captured and stored
- **Exempting CCS projects from the Emissions Performance Standard** where they are supported under the Commercialisation Programme

4.1. The strategy set out in this Roadmap focuses Government action on facilitating CCS in the power sector first with the industrial sector to follow. We have taken this approach because the power sector is the largest source of emissions – and therefore the sector which can contribute most to the reduction of those emissions. The power sector is also spread throughout the country, so the deployment of CCS will create a critical mass of transport and storage infrastructure which other emitters in the industrial sector will be able to tap into more cost effectively.

4.2. The Government's objective is to have competition between low carbon generation technologies in the 2020s with the market deciding which of the competing technologies delivers the most cost effective mix of supply and ensures a balanced electricity system. For CCS to be favoured in the long-term investors need to be confident that the technology will provide the benefits anticipated and that the electricity market will reward investment in CCS on an equivalent basis to other competing technologies.

4.3. The Government's interventions are intended to facilitate the development of CCS into a mature technology capable of being assessed by investors on a normal commercial basis. The Government has initiated widespread reform of the electricity market with the aim of providing a framework that will facilitate low carbon investment, including in CCS. Our aim is to create for the first time a market in which there is a clear commercial model for CCS in the UK, provided it can demonstrate the ability to compete with other low carbon technologies.

4.4. We will do this through our Electricity Market Reform (EMR) programme, which represents a significant opportunity for developers of CCS power projects, offering a unique set of incentives. These include:

- The prospect of long-term contracts that reflect the value of low carbon generation to the electricity market;

- Financial support for early stage CCS projects that will help overcome the additional risks associated with these early projects;

- An Emissions Performance Standard (EPS) set at a level to limit the emissions of new unabated coal fired power stations, but with exemptions for plants that install CCS;

- A Carbon Price Floor that, together with the EU Emissions Trading System, will penalise the combustion of fossil fuels – again there are exemptions for CCS; and

- A requirement for all new fossil fuel power stations to be Carbon Capture Ready, to ensure that newly constructed unabated fossil fuel power stations are able to fit CCS.

4.5. Within this reformed electricity market the main drivers for the deployment of CCS will be the level of decarbonisation necessary to meet climate change targets and the cost effectiveness of CCS compared with other forms of low carbon electricity with similar characteristics to CCS.

4.6. The Carbon Price Floor will make burning fossil fuels less attractive, thereby improving the relative competitiveness of lower carbon sources of electricity. Plants which install CCS will be exempt from the Carbon Price Floor in proportion to the CO_2 captured and stored and will therefore be treated the same way as other low carbon sources of electricity. EMR will provide each form of low carbon electricity with a Feed-in Tariff Contract for Difference (FiT CfD) set at a level that will enable developers to determine whether they wish to invest. The greater revenue certainty provided by the FiT CfD should lead to developers being able to reduce the costs of financing their investments.

4.7. We will consider incentives that might drive deployment of industrial CCS following completion of the work we intend to take forward to identify the current state of innovation and the barriers to deployment.

4.8. With these reforms and the other actions outlined in this Roadmap, we believe that there is now a clear route to market for CCS, which will in turn support the aspirations of the industry to deliver on its ambition for 20 - 30GW of CCS to be deployed by 2030, provided this is the most cost effective way of securing a flexible, secure and low carbon electricity system.

4.9. The Government believes that CCS has a potentially key role in the future decarbonised electricity market. In a world where low carbon capacity is incentivised by the market framework, the main constraints are likely to be the time taken to reach deployment of a reliable and cost effective technology (which will in turn be needed to unlock the private capital required) and the ability to overcome any physical constraints such as gaps in the supply chain or lack of a sufficiently skilled workforce.

Electricity Market Reform – working with industry

Wide-reaching changes to the electricity market will take time to develop and implement. Government is committed to engaging with industry throughout this process to ensure that the resulting market is fit for purpose and delivers the investment in low carbon infrastructure that the UK needs.

Further information on EMR was published in December 2011. This set out the Government's preference for the electricity market System Operator (National Grid) to administer the arrangements for the Feed in Tariff Contract for Difference and Capacity Mechanism, a decision to implement a Capacity Mechanism in the form of a Capacity Market, and also set out further details for enabling the investment decisions of projects required to take investment decisions before the EMR arrangements are fully implemented.

DECC will continue to work closely with industry to ensure that outstanding questions and design choices that impact CCS (and other low carbon) projects are resolved quickly and in the right way.

5. Learning by doing, learning by research

We are:

- **Launching a CCS Commercialisation Programme with £1 billion capital support** focused on learning by doing and sharing knowledge to reduce the cost of CCS so that it can be deployed in the early 2020s
- **Together with our partners, delivering a £125m, 4-year, co-ordinated R&D and innovation programme** covering fundamental research and understanding through to component development and pilot-scale testing; and establishing a new UK CCS Research Centre

5.1. Analysis of the costs of CCS show that one of the keys to achieving cost-competitive CCS is through technology development, both through learning by doing and through further innovation. To support early deployment of the technology the Government has put in place:

- A CCS Commercialisation Programme, enabling project developers to deploy early CCS projects and build real practical experience on the ground; and
- A co-ordinated R&D programme worth £125m over the next four years.

CCS Commercialisation Programme

5.2. The CCS Commercialisation Programme is focused on reducing the cost of CCS so that it can be deployed in the early 2020s. The Programme is outcome focused, with the aim of enabling private sector electricity companies to take investment decisions to build CCS equipped fossil fuel power stations, in the early 2020s, without Government capital subsidy, and at an agreed FiT CfD strike price that is competitive with the strike prices for other low carbon generation technologies.

5.3. Projects will be supported by the £1 billon capital funding which Government has already committed to the Programme as well as revenue support based on the clean electricity generated, and the EU's New Entrant Reserve for those projects selected by the European Commission.

5.4. This is one of the most comprehensive programmes offered by any country in the world to support the development of CCS. The Government is determined to work with industry to make the most of this opportunity.

Lessons learned from the first UK competition

A 'lessons learned' exercise was undertaken immediately following the decision not to pursue the Demonstrator 1 project. This, perhaps not unexpectedly, emphasised the need for speed, professionalism and thoroughness in managing the processes required to procure and negotiate a complex deal of this nature.

Of particular note was the conclusion that a lack of clarity regarding DECC's commercial position, particularly in relation to the sharing of risk and the project's overall financial envelope, meant that potential 'showstoppers' had not been identified and addressed early enough. The report suggested this led to unrealistic expectations on the part of the suppliers in relation to the nature of any final contractual arrangements.

The exercise also identified the need to:

- Adopt a collaborative approach with the market, using early engagement to shape procurement, prepare the market for proposals stage and build confidence in the programme;
- Maintain procurement tempo, setting out a realistic and well defined timetable to avoid extensions which can increase procurement costs and make projects vulnerable to external events; and
- Allocate risk where it can be most effectively managed and give a clear early signal of Government's intended risk allocation following an assessment of market appetite.

The National Audit Office have also undertaken an assessment of lessons to be learned from the Demonstrator 1 project[26]. The Government welcomes the NAO report, it highlights a number of important lessons and we are pleased that the report recognises that the costs of the competition were relatively small compared to the potential importance of CCS to delivery of an affordable, secure and low carbon energy system.

We have taken full account of the lessons we learned from the first UK competition to inform the design of the CCS Commercialisation Programme.

5.5. As well as learning from the first competition, we have undertaken extensive engagement with interested parties through ongoing meetings and two Industry Days, which were attended by Ministers and a number of Government Departments, as well as over 80 industry organisations. As a result we have developed a Programme that will enable the market to lead on identifying the route to commercialisation by minimising the constraints that we have placed around the solutions that competition bidders can propose.

[26] National Audit Office, 2012. Carbon capture and storage: lessons from the competition for the first UK demonstration. http://www.nao.org.uk/publications/1012/carbon_capture_and_storage.aspx.

Eligibility criteria

In order to deliver our Outcome, we have set the following eligibility criteria for entry into the competition. The eligibility criteria include that projects:

- May be full-chain or part-chain that can demonstrate the prospect of being part of a full-chain project in the future;
- Comprise a power plant and capture facility located in Great Britain and a storage site offshore;
- Must be able to be operational by 2016 - 2020, though earlier is desirable;
- Must abate CO_2 at commercial scale (or be a substantive step towards that objective) whilst meeting all relevant environmental requirements; and
- May contain an electricity generator or an industrial emitter which is part of a cluster project.

Further, in order to participate developers must have relevant expertise and experience of managing complex projects in this or a closely associated field, and the backing of at least one parent company with a significant balance sheet. Full details of the eligibility criteria are set out in the bid documentation, which registered bidders can access in the first month of the competition once signed Competition Process Agreements are returned.

In evaluating projects, we will favour projects that:

- Make the greatest contribution to reducing the future cost of CCS;
- Contribute to a sustainable future CCS industry, for example through the ability to link up multiple emitters (power and industrial) through shared infrastructure;
- Have strong and proactive knowledge transfer proposals;
- Provide wider benefits, such as facilitating new commercial opportunities like enhanced hydrocarbon recovery and contribute to the development of a CCS services sector and supply chain; and
- Contribute to wider government aims, such as strengthening the UK's energy resilience, and improving the option to effectively deploy CCS elsewhere in the world.

5.6. The Programme will consider a portfolio of commercial-scale projects including full-chain projects, part-chain projects where they demonstrate value for money and can show how the full chain will be implemented in the future, and cluster projects. Consideration will be given to the potential inclusion of industrial CO_2 emitters where they support cluster proposals. The selection of the projects that will comprise the portfolio will be limited by the overall affordability. Knowledge transfer that goes significantly beyond normal

commercial practice will be central to the Programme to enable others integral to the future deployment of CCS to learn from the supported projects.

5.7. The CCS Commercialisation Programme will support the development of a strong and robust supply chain in the UK, creating jobs and markets locally and nationally to serve the early CCS plant and later clusters of CCS activity. Playing to the UK's business strengths and favouring projects clustering in regions reflects the Government's ambition to capture opportunities for 'green jobs' that will arise from an emerging market for CCS, and recognises the concerns of UK industry about the development of CCS infrastructure. The Programme will deliver early projects that help maximise the benefits for CCS in the UK, and nucleate the sort of CO_2 transport and storage infrastructure that will be needed when CCS is more widely deployed.

Innovation

5.8. The Government has made significant investments in CCS research, development and innovation. This investment is already showing dividends – the UK's academic research is amongst the best in the world, international companies are choosing to collaborate with UK institutions and innovative new companies are emerging with technologies which could further reduce the cost and risk of CCS.

5.9. Progress has been made in the past few years, developing CCS technology and improving core understanding of issues which remain to be addressed. However, we need to increase our pace to ensure CCS can be deployed from the early 2020s and enable the UK to meet its 2050 climate reduction targets.

5.10. **We are launching a £125m, 4-year, co-ordinated R&D programme**. The programme will be wide ranging, covering:

- Supporting fundamental research and increased understanding [c£40m];
- Supporting component development and innovation [c£30m]; and
- Pilot-scale testing and projects [c£55m].

5.11. The UK needs to make clear progress towards achieving its 2050 targets, therefore the Government and its partners will focus the 4-year programme on priority areas as outlined by the academic and industrial CCS research community. Theses main areas are:

- Better, cheaper CCS components; and
- Improving knowledge and understanding of CO_2 storage.

£20 million for innovations in CCS technology

On 13 March 2012 the Energy secretary launched a competition worth up to £20 million to fund CCS innovation.

The competition is targeted at the development and demonstration of technologies associated with CCS, and on feasibility studies associated with using captured CO_2 from the Ferrybridge CCPilot100+ and Aberthaw capture pilots. The competition follows a similar call in 2011 from the Technology Strategy Board, and both are part of the Government's broader £125 million CCS R&D Programme covering 2011 - 2015.

The primary objectives of the Innovation Call are to:

- Successfully demonstrate, up to a scale of c10MWe, CCS components and technologies which could be subsequently incorporated into the supply chain of original equipment manufacturers (OEMs) and developers of commercial-scale CCS projects;
- Provide support to tackle the new challenges and innovation required to design and build components that – in terms of scale and/ or complexity – go beyond current understanding and experience;
- Generate learning and practical experience that can improve confidence in innovative CCS components and technologies and so help reduce future costs; and
- Ensure innovation support for CCS complements the existing research, development and deployment (RD&D) programmes being conducted in the UK.

The Innovation Call complements the Government's CCS Commercialisation Programme. Within approximately the next two years OEMs and project developers who are part of the CCS Commercialisation Programme could be placing orders for parts and therefore it is hoped that some of the components and technologies developed under this Innovation competition may become part of that supply chain and of future supply chains for subsequent CCS projects, both within the UK and beyond.

The competition will support innovative technologies associated with CCS for large single-point emitters of CO_2, such as fossil-fuelled power plants and energy-intensive industries. The challenge is to reduce the cost of CCS by developing more efficient, lower cost technologies, components and systems; and to develop understanding which reduces uncertainty and risk (and therefore leads to cost reduction) for any aspect of the CCS process.

Funding CCS R&D and Innovation

The Government funds energy R&D and innovation through four main bodies:

Department of Energy and Climate Change – Identifies gaps in existing R&D activities to ensure enhanced support is given to key technologies close to market and negotiates within the EU to ensure that EU funds are directed to areas that are a priority for the UK, including CCS;

Research Councils – Support fundamental research, creating new scientific knowledge and training the next generation of researchers;

Technology Strategy Board – Supports new innovation, moving ideas closer to the commercial market; and

Energy Technologies Institute – A unique partnership between the Government and industry, the ETI identifies and accelerates the development of affordable, clean and secure technologies by commissioning large scale system demonstrations.

5.12. An overview of future R&D needs is at Figure 6. A more detailed version was published in September 2011 by the Advanced Power Generation Technology Forum (APGTF)[27]. We will ask the APGTF to work with the UK CCS Research Centre (see below) to update this on an annual basis.

5.13. The UK is one of the world leaders on academic research on CCS. To better coordinate and promote this work, and to enhance the already high level of collaboration with industry, **we are establishing a new UK CCS Research Centre**[28].

[27] Advanced Power Generation Technology Forum, 2011. Cleaner Fossil Power Generation in the 21st Century – Maintaining a Leading Role. http://www.apgtf-uk.com/index.php?option=com_docman&Itemid=137.
[28] www.ukccsrc.ac.uk.

R&D Theme	Short term R&D needs (5 – 10 years)	Medium term R&D needs (7 – 15 years)	Long-term R&D needs (10 – 20+ years)
Whole systems	• Investigate system operability and power plant interaction between CO_2 grid • Test flexibility to cope with change in demand • Develop CO_2 accounting	• Further Investigation of complex interaction of CO_2 from multiple sources (capture technologies, industrial sources)	
Capture	• Learn from demonstration projects • Develop understanding of environmental impact • Identify requirements for retrofitting • Adapt technology for range of fuel types • Specify CO_2 standards • Establish common measures and monitoring	• Provide validation of demonstration capture technologies • Develop and demonstrate 2nd generation capture agents and processes	• Develop commercially available systems with >85% capture rate for all fuel types • Develop capture systems with efficiency >45% including CO_2 capture
Industrial CCS	• Investigate extent to which CCS technologies could apply to industrial applications	• Identify sources with sufficient operational lifetime remaining to make retrofitting feasible	
Transport	• Understand potential hazards and risks to inform decisions on pipeline routes onshore • Develop techniques for leak mitigation and remediation • Develop ship-based transport option	• Gather best practice data • Identify novel pipeline materials and sealing and joining technologies • Develop technologies to reduce power and cost of compression	• Develop performance database for CO_2 transport networks to enable grid optimisation
Storage	• Improve understanding of geological seal integrity and subsurface CO_2 behaviour/ flow • Estimate UK CO_2 storage capacity • Develop and demonstrate low-cost and sensitive CO_2 monitoring technologies • Develop best practice guidelines for well construction, completion and remediation	• Test injection at significant scale at multiple sites • Investigate water production • Develop techniques for rapid, detailed appraisal of formation capacity • Improve monitoring technologies	• Develop techniques for high efficiency use of formation capacity

Figure 6. Overview of future CCS research needs

5.14. The UK CCS Research Centre will promote a wide range of activity, in addition to supporting the core research, development and innovation activity. This includes:

- Encouraging the **development of shared R&D facilities** including a **new UK carbon capture testing hub**;
- **Collecting data from our various CCS research projects**; and
- **Development of people** to ensure we have the capability to use the knowledge generated from our R&D programme. The Research Councils doctoral training centres create 20 CCS PhD students each year, and as part of this **we will launch a new DECC CCS Internship Programme** of 2 students a year, to ensure our future CCS R&D leaders understand not only scientific and commercial aspects of CCS but also policy development.

UK CCS Research Centre

The new £13m Centre will bring together over 100 of the UK's top CCS academics, who currently manage an extensive portfolio of CCS projects. The Centre will aim to:

- Improve co-operation between UK researchers and global CCS industries;
- Focus on diverse skills and multiple innovations to accelerate solutions to CCS problems;
- Coordinate participating UK researchers to work on a programme of key strategic CCS priorities; and
- Gain understanding and accelerate the solution of large and complex CCS problems.

The CCPilot100+ capture project at Ferrybridge power station.

Photograph courtesy of SSE.

6. Tackling barriers to deployment

We are:

- **Implementing a regulatory framework** that enables and incentivises CCS projects whilst protecting the environment as a whole
- **Developing a storage strategy** to ensure that issues around the development of storage capacity on the scale that will be required are addressed in good time
- **Working with BIS and the sector skills councils** to ensure that UK industry has access to the skills and supply chains that will be needed to deploy CCS at scale
- **Engaging with industry on transport and storage infrastructure** to ensure that appropriate incentives are made available to support deployment of infrastructure

6.1. Although cost is the first hurdle to deployment of CCS, there are other key barriers which must be addressed if CCS is to be deployed at scale in the UK. Development of a new industry at the scale and in the timeframes envisaged will require:

- An enabling **regulatory framework**;
- A **storage strategy** that ensures sufficient capacity is available when required;
- People with the right **skills and supply chains** capable of providing the required goods and services; and
- A clear vision of how, where and when to develop **transport and storage infrastructure**.

Regulatory Framework

6.2. Regulation is one way in which the Government is able to influence the development and deployment of technologies such as CCS. Well-judged and timely regulation can be an important enabler and stimulus to technology development, effectively reducing the risk to developers by giving a clear framework in which they and Government will operate; but disproportionate or inappropriate regulations will act as a significant brake on technology development.

6.3. Creating the right regulatory environment is therefore crucial to the development and deployment of CCS. In the case of CCS some of this regulation will be generic, including requirements in respect of industrial emissions and of air and water quality. There is likely to be widespread experience of this regulation, but it is unlikely to have been designed

with CCS in mind. Other aspects of regulation will be specific to CCS but developed without the benefit of any practical experience. In either case, there will be uncertainty about the impact of the regulatory environment on CCS and the interface with local communities at the project level. One of the key objectives from the CCS Commercialisation Programme is to develop this practical experience to ensure that these activities are proportionately controlled and also that local communities are engaged to best effect. Indeed, CCS projects need to learn from experience to date which suggests that community engagement begins early and goes beyond the requirements under the regulatory regime.

6.4. The UK is leading the world in the development of a regulatory framework to facilitate CCS whilst protecting the environment taken as a whole. The Government undertook a comprehensive review of the regulation necessary to enable CCS in 2007 and that review concluded that the established regulatory framework was suitable for the permitting of all of the activities associated with CCS, except for the permitting of permanent storage. We are continuing this lead by quickly addressing barriers when they are identified, for example by amending the Petroleum Act to remove an impediment to early projects.

Amendments to the Petroleum Act

When a barrier to the reuse of existing capital assets for the purpose of CO_2 storage and transport was identified the Government acted quickly to ensure that this would not delay or lead to the cancellation of projects.

Energy Act 2011 includes discretionary powers for the Secretary of State to designate an offshore installation or pipeline which, when the designated installation is used for the purpose of CCS demonstration, removes the possibility that the organisation that had previously used the facilities only for petroleum production activities can be made liable for its decommissioning.

6.5. CCS has important potential benefits to air quality, although these depend upon the carbon capture technology. Pre-combustion systems remove sulphur before combustion, thus removing the subsequent need for removal of sulphur dioxide emissions from combustion. The oxy-fuel variant requires greatly reduced nitrogen dioxide concentrations in the gas stream to be treated, thus probably necessitating both flue gas desulphurisation (FGD) and selective catalytic reduction (SCR) to be applied ahead of the capture process. However, capture processes could, if not tightly controlled raise other emission issues. The CCS Commercialisation Programme will provide important learning to enable appropriate regulation to develop.

6.6. Capture processes increase the water use of the host power station which could be particularly significant if a number of such power stations were to be abstracting water from the same source. Recent work by the Environment Agency suggests that there are significant future risks of increasing water scarcity driven by climate change and

population growth[29]. DECC is working closely with Defra, the Environment Agency and industry to understand the implications of these risks for CCS deployment. The Government has committed to reform water abstraction regulations to help water abstractors such as power stations more efficiently meet their water need while protecting water ecosystems in the face of these increasing risks.

Scottish regulatory test exercise

In anticipation of several large-scale CCS projects coming forward in Scotland, the Scottish Government formed a Regulatory Group in 2009, to consider the various permits required across the entire chain of CCS activities. A key action from this Group, was to test the effectiveness of the existing regulations by using a mock CCS project at a two day workshop event held in August 2010. The workshop maximised learning opportunities by involving government departments, regulatory agencies, developers, planners, academics and NGOs. Consequently, a readout report was published, setting out the findings of the test exercise and the actions to be taken forward by stakeholders.

Following the test exercise, the Scottish Government in conjunction with the Scottish Centre for Carbon Storage published a CCS Regulatory Test Toolkit. This Toolkit was fully sponsored by the Global CCS Institute who also proactively participated in the workshop held in Glasgow. This regulatory test dovetails well with the regulatory model developed by IEA which is also included in the Toolkit which has been subsequently commended by the Commission as a model of best practice for regulation that could be rolled out by other Member States. The CCS Regulatory Test Toolkit is available at http://www.scotland.gov.uk/Topics/Business-Industry/Energy/resources/Publications/CCSRegulatoryToolkit

A key outcome from the test workshop has been to set up a CCS Programme Monitoring Board which first met in January 2011. The aim of the Board is to ensure that Government, regulators and developers agree and track a timetable for project delivery that is consistent with the requirements of funders and with the statutory processes set out in regulations.

Through connections set up by the Global CCS Institute, the Scottish Government has proactively advised the governments of Canada and Romania who have expressed interest in using the Toolkit. Work continues with the European Commission to promote the Toolkit amongst other Member States and amongst networks of EU energy and environment regulators. Engagement with DECC, the Scottish Centre for Carbon Storage, the Global CCS Institute and Scottish Enterprise is ongoing, to discuss regulatory frameworks, network planning co-ordination, transboundary projects and knowledge sharing on CO_2 transport to assist in the development and deployment of CCS.

[29] Environment Agency, 2011. The Case for Change – Current and Future Water Availability. http://publications.environment-agency.gov.uk/PDF/GEHO1111BVEP-E-E.pdf.

6.7. We will continue this proactive approach to implementing an enabling regulatory framework by:

- Ensuring that the CCS Commercialisation Programme tests the regulatory framework – it is likely that lessons will be learnt as projects develop so it is essential that Government seeks to test the regulatory framework, including practice by CCS projects on effective community engagement, identifying lessons early and taking action in advance where possible;

- Undertaking a regulatory test exercise in England on one of the early CCS projects (if any are selected in England) to develop practice by CCS projects on effective community engagement and to ensure that projects in UK and EU competitions can be delivered to required timescales and explore the implications of managing the permitting regime to support clusters;

- Facilitating CCS projects to learn about approaches toward community engagement; and

- Consulting industry in advance of the European Commission's review of the CCS Directive in 2015 to ensure that UK experience is shared across the EU.

Storage strategy

6.8. The UK is potentially ideally placed for CCS, given we have well understood sedimentary basins near to clusters of point source CO_2 emissions, particularly on the coasts of the North and east Irish Seas. The potential stores are in (i) depleted hydrocarbon reservoirs, (ii) producing fields with the addition of CO_2 enhanced hydrocarbon recovery and (iii) deep saline aquifers.

6.9. To meet the 2050 target, assuming CCS plays a role, the UK could need to safely and permanently store between 2 and 5 billion tonnes of CO_2 by 2050, increasing to perhaps 15 billion tonnes by the end of the century.

6.10. Our work to date has focused on enabling CCS to take place. If industry's ambition for the deployment of CCS are to be realised we need to look in more detail at the management of our offshore assets. DECC will meet with the industries and organisations with interests in the current use of the seabed, to facilitate effective planning by all parties, aiming toward an orderly sequencing of North Sea operations and investment. We will seek to establish a shared vision of how large-scale CO_2 storage could develop and how storage site appraisal can be progressed. Without these steps there is a danger that identifying "bankable" storage capacity will become a critical path item in the CCS chain.

6.11. The CCS Commercialisation Programme is a key step in providing knowledge and confidence around the performance of CO_2 storage sites. It is the Government's intention that the Programme will support large-scale storage sites, providing essential experience of the steps needed to evaluate, develop and operate such a store.

6.12. It could be considered that a long-term programme of validating saline formation storage sites is necessary to complement the full scale testing in the CCS Commercialisation Programme, and to ensure that the availability of suitable storage sites does not impede future deployment of CCS. We will therefore discuss with industry partners what such a programme could entail and publish a further update of this storage strategy by the end of the year.

6.13. It is envisaged that the objective of the programme will be to reach a point by the 2020s whereby a company would be prepared to take a final investment decision to utilise the site to store CO_2, and that the regulators would have enough information to inform their decision on whether to license such a site.

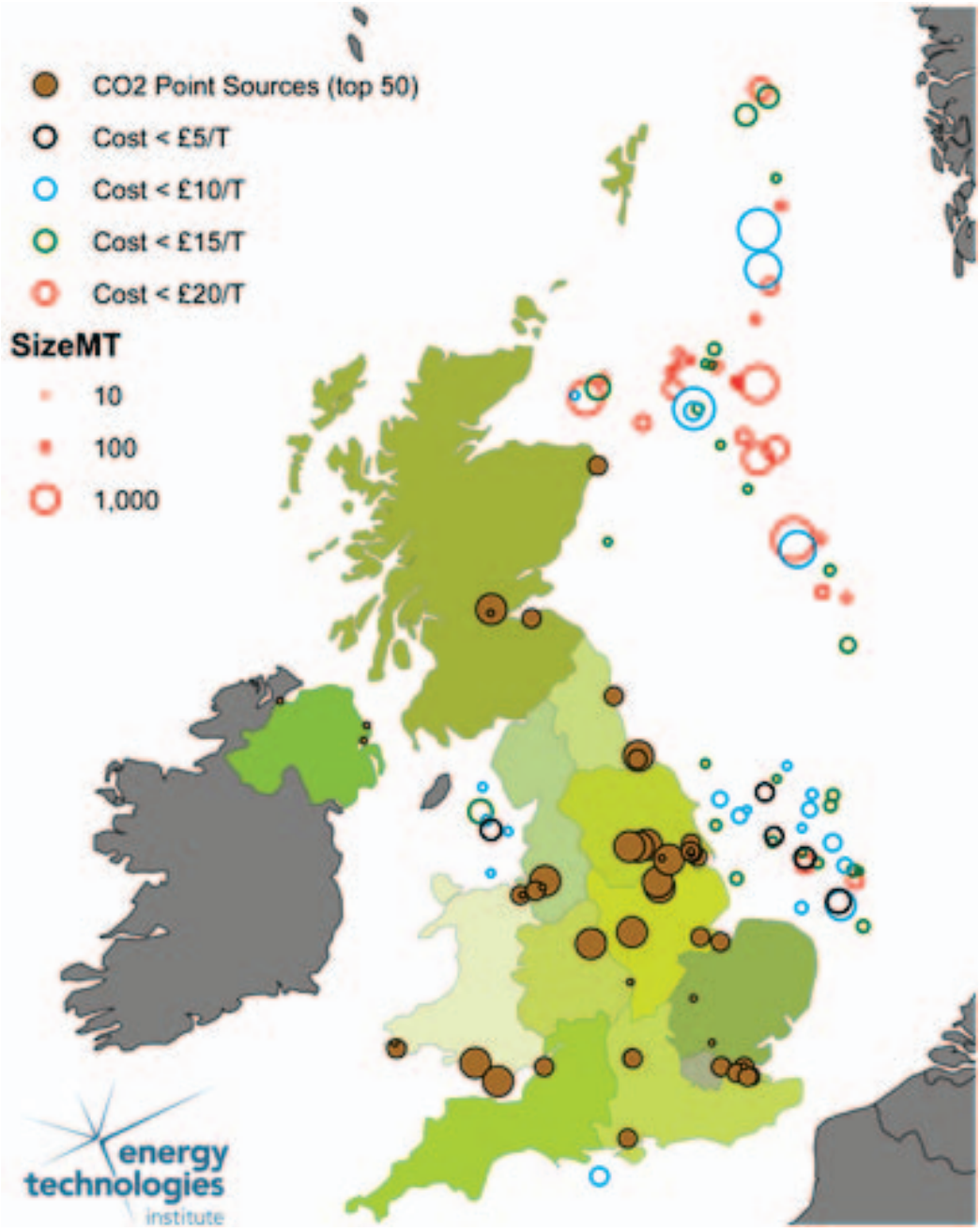


Figure 7. Proximity of the UK's largest industrial emitters to least cost storage capacity in the North and Irish Seas. Costs are undiscounted and on a "source to sink" basis. Map provided by the Energy Technologies Institute.

Study on UK storage capacity

A study recently completed by the Energy Technologies Institute (ETI) concluded that the potential storage capacity of the UK could be up to 70 billion tonnes. This is a considerable natural asset for the UK which, if realised, could provide enough capacity to store not only UK CO_2 emissions but also CO_2 emissions from Europe. The 3 year study, part funded by Government, examined nearly 600 storage sites using existing data and information. The study not only confirmed the potential capacity of the UK storage sites, but also highlighted the need for further work.

The key findings included:

- The UK has storage capacity potential to meet its CCS needs of up to 15 billion tonnes over the next 100 years – of the total estimated capacity, approximately 9 billion tonnes exist in depleted oil and gas fields and up to 60 billion tonnes in saline aquifer stores;
- Useful storage exists all across the North Sea and in the East Irish Sea. The costs of using the stores identified spanned two orders of magnitude, so selection will play a key role in minimising CCS costs;
- Although there is sufficient potential storage space available this does not mean that all storage capacity is well enough understood for storage permits to be granted – at present hydrocarbon fields are understood better than saline aquifer stores. To unlock the UK's storage potential, further assessment of saline aquifer stores is required;
- It is uncertain when the storage capacity in individual hydrocarbon fields will become available for storage due to the unpredictability of field cessation-of-production dates (which depend on highly uncertain factors like the oil price) and the possibility of other commercial applications for the sites – if one assumes that some sites will not become available when needed, then relying solely on depleted oil and gas fields may impact on the future deployment of CCS; and
- Given this uncertainty over the timely availability of storage in hydrocarbon fields and long lead times (between 6 – 10 years) required to assess saline aquifer stores, further assessment of saline aquifers needs to begin now – this will help the UK to avoid reaching a pinch point in the late 2020s where insufficient storage capacity is available.

Long-term storage liability

6.14. For a properly selected and operated store there is a high level of confidence that CO_2 will remain in the store permanently. However, the CCS Directive places obligations to remediate a store in the unlikely event that CO_2 does not remain within the storage site as intended. There is currently no accepted basis for estimating the true exposure to these potential liabilities and this is proving to be a major obstacle for prospective storage site

developers. The Government believes that more evidence is needed to help develop a more realistic estimate of these risks. We have therefore commissioned work to help develop a common understanding on the extent of these risks, we hope this will help to develop a consensus about the scale and most effective approach to managing these risks. We believe that such evidence will also be useful in helping the financial services sector develop third party risk mitigation products (such as insurance). Once this initial work is complete we would hope to take it forward with the support of the CCS industry.

Transport and storage infrastructure

6.15. The development of the infrastructure necessary to transport and permanently store CO_2 is one of the key challenges to achieving the objectives set out in this Roadmap.

6.16. The availability of pipelines and storage sites that enable high emitting industries to contract for the transport and storage of CO_2 on a similar commercial basis to other utility services will be one consequence of the widespread deployment of CCS in the economy. Some proponents of CCS go further – arguing that the development of infrastructure will be a pre-requisite for the widespread deployment of CCS on the scale needed to meet the Government's low carbon electricity objectives.

6.17. It is not the role of the Government to plan the generation of electricity (or more broadly the make-up of the economy) at the level of detail implied by those ambitions but there are steps Government can take through this Roadmap and interventions in the market more generally that will facilitate the development of CCS infrastructure. We will tailor those interventions so they encourage cost effective investment in CCS infrastructure, recognising that the overall thrust of government policy is for infrastructure to be privately owned and financed. We are:

- Assessing the need for public finance for infrastructure deployment in the CCS Commercialisation Programme;
- Keeping the economic regulation arrangements for pipelines under review;
- Assisting those looking to develop regionally focused CCS activities; and
- Exploring sources of finance with potential investors, including new routes such as the Green Investment Bank and funding to support regional growth.

The Goldeneye Platform. DECC funded FEED work on the Goldeneye reservoir to explore its potential for geological storage of CO_2 from the Longannet Power Station.

The results of this work can be found on the OCCS website at:
http://www.decc.gov.uk/en/content/cms/emissions/ccs/demo_prog/feed/feed.aspx

Photograph courtesy of Shell UK Ltd.

An industry view on infrastructure

The CCS Association have argued that the benefits of right-sizing CCS transport and storage infrastructure are clear but private companies are currently unwilling to invest due to uncertainty around the risk-reward balance in the absence of a clear and robust long-term CCS policy in the UK and a commitment from Government to share the financial risks involved.

The key messages highlighted by the CCSA are:

- The urgent provision of right-sized CCS transport and storage infrastructure is vital – particularly considering the long lead times for planning and development of CCS transport and storage infrastructure, the pressing need for decarbonisation of industry and the rate of decarbonisation required in the power sector;
- It is vital that Government creates a follow-on market for CCS beyond early projects, to enable the industry to make a business case for CCS infrastructure (and indeed for the early CCS projects themselves);
- A firm long-term policy on CCS is required before early CCS projects reach final investment decision stage to galvanise industry investment in CCS (and CCS infrastructure) – EMR can provide this firm long-term policy;
- Government should be prepared for some measure of risk-sharing with industry to enable right-sized CCS infrastructure;
- There are a number of options that could be considered to leverage investment in right-sized CCS infrastructure – it may be that a mix of options will be most appropriate, however this will be different for each CCS project and cluster; and
- Urgent action is required to qualify sufficient storage capacity to store anticipated levels of captured CO_2 that will be forthcoming in the next few decades.

Skills and supply chain

6.18. There are clear advantages to economic growth from ensuring that local companies have the capability to supply technology and skilled workers to CCS projects, and attract new suppliers to set up and manufacture in the UK. For example, the UK's first capture pilot at Ferrybridge has provided opportunity for more than 20 UK based suppliers.

6.19. The supply chain for constructing integrated CCS projects will be complex and a range of business and contractual relationships will emerge as the sector matures. Much of the supply chain is expected to involve existing businesses activities (e.g. boiler and steam turbine design and manufacture), with the remainder in new applications of existing activities associated with CCS services (e.g. design and manufacture of capture, transport and storage facilities).

6.20. Similarly a wide range of skills will be required from a strong pool of skilled people for the successful development and deployment of CCS to proceed. Many of the skills needed exist in the UK workforce because they are already utilised by other related industries including power generation, chemical and process engineering, pipelines, offshore engineering and geological exploration; however many of these sectors report shortages of skilled staff.

6.21. The challenge is to ensure that we are able to identify and address gaps in the UK skills base and supply chain. To ensure that the UK is well prepared to deploy commercial CCS in the early 2020s we are:

- Undertaking initial supply chain mapping as the basis for future work connecting opportunities and weaknesses in the supply chain, working with key sectors and their trade associations to ensure the UK is best placed to play an effective part in the long-term development of CCS – this work will take part throughout the development phase of CCS and into full-scale deployment;

- Working with and influencing key organisations such as BIS, UKTI and the sector skills councils to ensure that the needs of the CCS industry are taken into account in wider skills related interventions – developing skills is a key factor in the introduction of low carbon technologies and it is essential that CCS related skills do not fall behind those needed by other developing technologies; and

- Investigating current initiatives such as the Advanced Manufacturing Supply Chain Initiative, the Regional Growth Fund and other schemes as they are introduced, to see how they can support projects that will impact on supply chain, skills and economic growth, as well as projects which would support supply to a sustainable CCS industry.

6.22. Emerging results from AEA Technology's study on the non financial barriers to the commercial deployment of CCS indicate that the UK supply chain has the necessary expertise and capability to deliver a major part of the demand during the early commercialisation phase. However, the CCS capacity and corresponding demand for CCS-related components, services and skills are expected to increase significantly after that, and so the UK supply chain needs to develop in parallel to fill the gap. This provides an opportunity for existing UK companies to develop their businesses to capture a significant share of the domestic market and to expand globally.

6.23. One of the main issues highlighted by the study is an expected decline in the number of UK engineering specialists and experts in the coming decade. However, greater demand for these skills following the commercial deployment of CCS (alongside other low carbon technologies) is opportunity to offset, and even reverse, this decline. There is no room for complacency: ensuring enough skilled workers are available domestically, particularly when CCS will be in competition with other low carbon technologies, will be crucial to the successful roll out of commercial CCS.

6.24. Other than skills, the study indicates that the roll out of CCS will lead to a large increase in demand for CCS-related components and services. This also represents an opportunity for UK supply companies to grow to meet these future needs. Encouragingly, however, the study's emerging results suggest that there are no non-financial supply chain barriers that will act as an impediment to domestic supply chain growth.

Tackling non-financial barriers

Government recognises the importance of ensuring that no aspect of the supply chain acts as a barrier to the future deployment of CCS. DECC recently commissioned AEA Technology to examine the non-financial barriers to the commercial deployment of CCS within the UK power sector.

The study examines the ability of the UK supply chain to deliver the UK's CCS needs in the future. Engagement with stakeholders across the CCS supply chain, to determine their views on any barriers to the UK supply chain, forms a crucial part of this study.

This study, however, is not just limited to indentifying supply chain barriers; by looking at future needs, and the ability of the UK to deliver those needs, the study also highlights opportunities for future growth in the UK supply chain following the roll out of commercial-scale CCS within the UK.

DECC will carefully examine the study's findings, and consider ways of addressing any supply chain barriers the study indentifies. We will also share the findings with the CCS Development Forum to ensure that we fully understand the implications of any barriers the study indentifies and take views on how to address them. If newly identified barriers emerge from the study that need to be tackled we will add them to our action plan.

Value chain category	UK Capability			Global capability		
	Low	Moderate	High	Low	Moderate	High
CO_2 Capture						
Post-combustion capture	0	3	4	0	1	6
Pre-combustion capture	2	5	0	0	2	4
Oxyfuel	3	3	1	1	5	1
Balance of plant	0	4	3	0	1	6
Design, build and commissioning	0	1	6	0	0	7
Operation and maintenance	0	2	5	0	2	5
Monitoring and testing	0	6	1	0	6	1
R&D	0	2	5	0	2	5
Consultancy	1	2	3	0	3	3
CO_2 transport						
Design, build and commission	1	1	4	0	2	4
Pipeline suppliers	1	1	4	0	1	5
Welding services	0	2	4	0	1	5
Pipeline risk assessment	1	1	4	0	2	4
Network management	2	0	4	0	2	4
R&D	0	2	4	0	1	5
Consultancy	0	2	4	0	1	5
CO_2 storage						
Injection well design, build and commission	0	3	3	0	2	4
Reservoir operations	0	2	4	0	1	5
Field services	1	1	4	0	2	4
CO_2 monitoring instrumentation	2	4	0	1	5	0
R&D	0	2	4	0	1	5
Consultancy	0	3	3	0	2	4
Related activities	2.00	1.20	3.40	0.80	2.80	3.00
Legal services related to CCS	1	1	4	0	2	4
Financing and insurance services	5	0	2	3	2	2
Environmental impact assessment	1	1	5	1	3	3
Planning	2	1	4	0	3	4
GHG accounting and verification	1	3	2	0	4	2

Figure 8. Summary of stakeholder responses on the capability of the UK supply chain from AEA's emerging study on the non-financial barriers to CCS

7. Further Detail

7.1. Alongside the Roadmap we are publishing a series of supplementary documents that set out more detail across 6 major themes:

- CCS Commercialisation Programme;
- Innovation and R&D;
- Regulatory framework;
- Storage strategy;
- Skills and supply chain; and
- Transport and storage infrastructure.

7.2. These documents are available on the DECC website at www.decc.gov.uk/occs. They will be kept up to date and used by the CCS Development Forum to track progress.

8. Action Plan

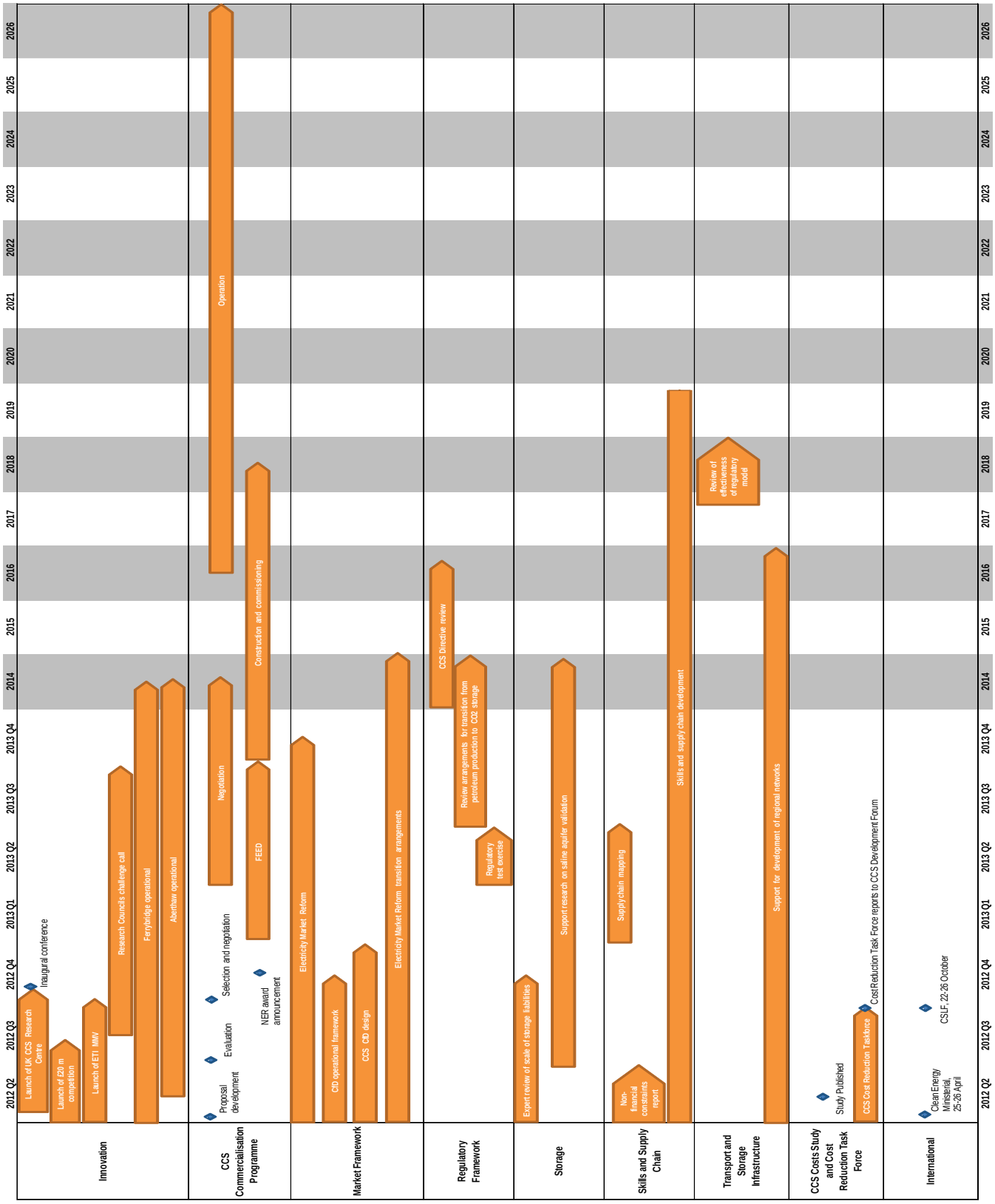


Figure 9. CCS Action Plan.

A larger version is available from the DECC website at: www.decc.gov.uk/occs.

9. Summary of Actions

Understanding the challenge

- Intending to publish a study identifying and estimating potential CCS cost reductions
- Asking an industry led CCS Cost Reduction Task Force to set out an industry view of what needs to be done to make CCS cost-competitive with other low carbon technologies – building on the study and other evidence the Task Force will set out findings and make recommendations for further action to realise reductions in the cost of CCS
- Working with other leading Governments, the Global Carbon Capture and Storage Institute and the European Commission to ensure that knowledge and lessons learned in the UK and overseas are shared to inform a best practice approach
- Focusing the other actions in this Roadmap, including the new CCS Commercialisation Programme, on reducing the cost of CCS to ensure that it is commercially deployable in the early 2020s
- Working with the industrial sector to identify the current state of innovation on CCS and the potential for Government interventions to enable deployment
- Working with the industrial sector to identify the barriers and opportunities to industrial CCS and the potential role for Government

Enabling commercial CCS

- Reforming the electricity market to enable investment in low carbon power generation
- Developing long-term contracts (EMR FiT – CfDs) which recognise the potential contribution of CCS to a balanced low carbon electricity system
- Exempting power stations with CCS from the Carbon Price Floor in proportion to the CO_2 captured and stored
- Exempting CCS projects from the Emissions Performance Standard where they are supported under the Commercialisation Programme

Learning by doing, learning by research

- Launching a CCS Commercialisation Programme with £1 billion capital support focused on learning by doing and sharing knowledge to reduce the cost of CCS so that it can be deployed in the early 2020s

- Together with our partners, delivering a £125m, 4-year, co-ordinated R&D and innovation programme covering fundamental research and understanding through to component development and pilot-scale testing, and establishing a new UK CCS Research Centre

Tackling barriers to deployment

- Implementing a regulatory framework that enables and incentivises CCS projects whilst protecting the environment as a whole

- Developing a storage strategy to ensure that issues around the development of storage capacity on the scale that will be required are addressed in good time

- Working with BIS and the sector skills councils to ensure that UK industry has access to the skills and supply chains that will be needed to deploy CCS at scale

- Engaging with industry on transport and storage infrastructure to ensure that appropriate incentives are made available to support deployment of infrastructure

Department of Energy & Climate Change
3 Whitehall Place
London SW1A 2AW
www.decc.gov.uk

URN 12D/016