Institution of Civil Engineers

Carbon capture and storage: time to deliver

October 2009

About ICE

The Institution of Civil Engineers (ICE) is a global membership organisation that promotes and advances civil engineering around the world.

ICE is a leading source of professional expertise in transport, water supply and treatment, flood management, waste and energy. Established in 1818, it has over 83,000 members throughout the world, including over 60,000 in the UK.

ICE's vision is to place civil engineers at the heart of society, delivering sustainable development through knowledge, skills and professional expertise.

Contents

Cover image: Schwarze Pumpe power station in Germany, the location of a new Oxyfuel pilot plant. The pilot plant is an important milestone to reach the goal of commercial concepts for carbon capture and storage at coal fired power plants by 2015-2020. It will be the first pilot plant in the world to use the Oxyfuel capture method. Carbon dioxide captured in the pilot plant will have the right properties to be transported and permanently stored deep underground.

Foreword

The UK Government and Committee for Climate Change's proposals for reducing UK carbon emissions by 80% against 1990 levels by 2050 include a key role for carbon capture and storage (CCS) working at a commercial scale.

In this booklet, ICE has brought together six leading experts on different aspects of CCS, to explore the steps that need to be taken to deliver CCS in the UK. These comprise three key elements:

- capture of the CO_2 emissions from a concentrated point source, such as coal and gas power stations, cement kilns and steelworks
- transport of the CO_2 to the final storage location
- permanent storage of the CO_2 in a stable and sealed geological formation

The development of carbon capture and storage is not an academic exercise; it is a practical challenge with the potential to be a key part of the response to the threat of climate change. It presents an opportunity to utilise the UK's world class engineering base to develop the capability to serve domestic needs and create an export opportunity.

To unlock the potential, CCS must be proven to be viable both technically and economically. The proposed UK CCS demonstration programme will be an important step in confirming the practical capability of CCS.

To make the most of this opportunity, ICE believes government needs to provide a supportive environment by implementing the following policy recommendations, to support both the demonstration programme and the commercial scale developments that may follow.

- Political certainty: establish strategic level certainty by:
  - producing a National Policy Statement on carbon capture and storage alongside those already in production for other aspects our energy system
  - producing a clear road map for the development of CCS capacity, with deadlines for the completion of government's actions around planning, licensing, regulatory regime et al. Given the likely potential of CCS to help meet our emissions targets, this roadmap should be owned by the senior Minister charged with making regular reports to parliament on the UK's low carbon energy supply

- ▪Technological freedom: send out a clear signal that within this strategic framework, government should not try to micro-manage the technical development of CSS, providing industry with the freedom required to innovate

- Legislation: promote the process of technological development and assessment through the demonstration programme to adapt legislation, planning and regulation to mirror the emerging requirements of CCS as it is proven

Paper 1

Carbon capture and storage – an essential part of our low carbon economy

By Dr Jeff Chapman, Chief Executive, The Carbon Capture & Storage Association

Introduction

Carbon capture and storage (CCS) is urgently needed as a fundamental part of the global fight against climate change. Both developed and developing countries rely largely on fossil fuels to provide energy and demand for that energy is ever increasing. CCS can be used to capture approximately 90% of CO_2 produced when fossil fuels are burnt at large point sources, such as power stations. It therefore has a crucial role to play in tackling greenhouse gas emissions whilst maintaining security of supply, and must be deployed alongside other low-carbon options (including nuclear and renewable generation) if emissions targets are to be met. These targets include the UK's 80% target for reductions in CO_2 emissions by 2050, as well as the recommendation made by the Committee on Climate Change that the UK's electricity sector needs to be decarbonised by 2030.

It is important to note that CCS is the only low carbon option for many industries beyond the power sector, including steel and cement production. It also has exciting potential for producing carbon negative power when used with biomass. In addition, CCS enables clean production of both electricity and hydrogen, which will be essential for decarbonising sectors such as transport and heat.

Deploying CCS in the UK

All elements of the CCS chain have been demonstrated and proven – smaller scale CCS projects are already operational around the world. The next step is to build commercial scale CCS plants that demonstrate the full chain together (from capture through to storage) in order to minimise costs and maximise performance.

The EU has a target of 10 to 12 CCS projects to be constructed and operating by 2015, and the G8 recently reaffirmed their commitment to seeing 20 large-scale CCS projects launched across the world by 2010. Industry has already invested millions in CCS and, as demonstrated by the various calls for projects, including in the UK and Alberta (Canada), there is no lack of interest in building these projects.

However, as is the case with other low-carbon technologies, additional public support will be needed to overcome early mover risks. Lack of sufficient incentives for CCS is arguably the major barrier that is currently slowing deployment.

The main mechanism for incentivising all low-carbon technologies (in Europe) into the future is the EU Emissions Trading Scheme (ETS) and it is expected that CCS will become self-financing within the EU ETS at a future date (perhaps in the 2020s). At present the carbon price is too low and volatile for this to be the case and additional support is therefore required to accelerate early deployment in order to meet the ambitious timetable that is needed to address climate change.

In the UK the government has proposed a levy on electricity suppliers to fund up to four CCS demonstration projects. This move has, of course, been welcomed by the CCS industry, although the details have yet to be finalised. Other important examples of funding include 1.05 billion Euros for CCS projects across seven EU countries, as part of the European economic recovery package and the agreement to allocate 300 million allowances from Phase III of the EU ETS to support CCS projects (as part of the EU Flagship Programme) and innovative renewables. How this funding will be dispersed has yet to be decided. Elsewhere in the world, Australia and the province of Alberta in Canada have also announced support for early projects, and the US has several funding programmes for CCS projects and R&D (including as part of its own economic recovery package).

These announcements of support are, of course, important developments for CCS and should help to move projects forward. However, further incentives will be needed to accelerate early deployment of CCS around the world and realise an ambitious timetable for CCS plants coming online. To give an indication of the scale of deployment that is required, the International Energy Agency (IEA) has estimated that to achieve a 50% reduction in global CO_2 emissions by 2050, 80 CCS power plants will need to be brought into operation every year from 2030 (in addition to an ambitious deployment of other low-carbon technologies). The IEA has estimated that CCS (applied to both power stations and other industrial CO_2 sources) will account for nearly 20% of emissions reductions by 2050 and that without CCS the cost of abatement will rise by 70% (equivalent to $1.28 trillion annually).

When considering incentives for CCS, it is important to remember that deployment of CCS will also depend on the timely development of CO_2 infrastructure. In particular, support should be considered to encourage clusters of CCS projects that could benefit from shared CO_2 pipelines, and hence achieve economies of scale as well as developing a network that other industrial emitters can link into. With sufficient support, the first four projects in the UK could present an opportunity to stimulate the development of such infrastructure.

Alongside incentives, appropriate regulatory frameworks for CCS activities also need to be introduced. The EU agreed the CCS Directive at the end of 2008 (as part of the climate and energy package) and it is important that Member States transpose this into their own legal systems as quickly as possible to create a solid legal basis across the EU for investment in CCS.

The race for CCS

2009 could prove to be pivotal for CCS and the issue of climate change as a whole. December's UNFCCC meeting in Copenhagen will discuss a global climate change deal and it is vital that CCS is strongly recognised in this agreement. There are also other key events of significance in the run up to the UNFCCC meeting, including the Carbon Sequestration Leadership Forum (CSLF) ministerial meeting in October in London.

In the UK there is no doubt that CCS will be an essential part of our low-carbon economy. Not only will this set of technologies to capture, transport and permanently store CO_2 address emissions from power stations and other industrial sources of CO_2, but it will also enable a diverse and secure energy supply (including providing intermittent renewables with clean and flexible back up generation). CCS will create thousands of jobs and could become an enormously valuable export market for the UK, providing that immediate action is taken to capitalise on our current position.

To date, the UK has shown leadership in announcing its competition for a demonstration project in 2007 and introducing regulation for CCS. However, other countries are now catching up and indeed overtaking the UK. The province of Alberta in Canada, for example, announced its own competition for $2 billion of funding for demonstration projects in July 2008. Three projects have already been selected, whereas the UK has yet to decide on a winner for its original competition.

The next steps for the UK include announcing that competition winner and putting the levy to fund these pioneering CCS projects in place as soon as possible. The selection of the four UK projects (and it should be four, not "up to four") that will benefit from this funding should take place as part of an ambitious timetable of deployment, with the aim of enabling CCS to be commercially viable in the early 2020s. Selecting and constructing these projects sequentially will not maximise our chances of reaching that goal. It is also important to recognise that these projects should be viewed as the first phase of CCS deployment in the UK and not just as a technology demonstration programme.

Every year of delay to the commercial deployment of CCS sees increasing and cumulative amounts of CO_2 being pumped into the atmosphere, increasing the scale of the challenge that tackling climate change presents and imposing environmental costs on future generations. We must therefore deploy CCS with urgency if the full potential for emissions reductions that it can bring is to be realised.

The UK has placed itself well to lead the world on CCS, but it must act now if the full benefits of having initially acted early are to be realised, both to the climate and to the economy.

By Dr Jeff Chapman, Chief Executive, The Carbon Capture & Storage Association

Jeff Chapman established the Carbon Capture & Storage Association in March 2006 after over 30 years of management experience in industry, consultancy and more latterly in government circles. The Association works to represent the interests of its 75 members in the business of capture and geological storage of carbon dioxide.
e info@ccsassociation.org
t +44 (0) 20 7821 0528

Paper 2

Carbon capture – the technologies

By Peter N Whitton, Managing Director, Progressive Energy Ltd

1. The scope of the capture requirement

Carbon dioxide is released in many industrial processes that use oil, gas and coal as the feedstock for the process. The major applications utilise the energy content – for heating, for electricity generation or in engines in cars and in other transport applications. This fossil feedstock is also utilised in a host of chemical processes to manufacture steel, fertilisers, plastics and many other products. In most cases carbon dioxide is released as part of the process.

The capture of carbon dioxide is of relevance in all these cases but the key requirement is to minimise carbon dioxide release from combustion as this is by far the dominant source of CO_2. The focus is on electricity generation because of the scale of the release. The carbon intensity of electricity generation from coal is twice that of natural gas so for every unit of electricity made twice as much CO_2 is released. Given that coal is plentiful and widely used around the world carbon capture from coal generation is the priority.

2. The status of carbon capture technology

The common perception is that carbon capture technology is not available for use at a commercial scale now. A frequently voiced view is that the technology requires scale up and demonstration which will take decades. This is not the case.

The reality is that there are several different capture technology alternatives, each with its own advantages and disadvantages and each at a different stage of development. The fundamental division is between 'pre-combustion' and 'post-combustion' capture technologies.

2.1 The post-combustion approach

In a conventional coal power station coal is burnt, the heat captured in a boiler and used in a steam turbine. Post combustion capture, sometimes called 'end of pipe' solutions seek to capture CO_2 after the coal has been burnt in the power station. The gases discharged from the chimney contain CO_2 and these capture technologies aim to separate and concentrate it so that it can be piped away for storage. Post combustion capture technologies for such power station applications are immature and do require scale up and proving. In Europe the largest facility currently operating demonstrating post combustion capture is in Denmark at Eisberg, where a test facility is attached to a coal fired power station. The scale is equivalent to 8MW against normal power station sizes of 1000MWe or more.

However, worldwide, post combustion capture is receiving a tremendous amount of attention, and the technology is advancing rapidly and for demonstration at 120MWe and higher are well advanced. Some manufacturers of post-combustion capture equipment, notably the Japanese company MHI and the French company Alstom, believe that they will be in a position to offer post-combustion capture equipment at scale on a fully commercial basis by around 2015.

2.2 The pre-combustion approach

An alternative to burning coal directly as in a conventional power station is to first turn the coal into a gas and burn the gas in a combined cycle gas turbine (CCGT). CCGTs have been the investment of choice for the past 20 years in the UK to utilise natural gas from the North Sea. The advantages of this approach are that the synthetic gas contains a high concentration of CO_2 which can be more easily and cheaply separated for storage than is possible, or expected to be possible, for the post combustion capture approach. Fitting capture to a conventional power reduces its overall efficiency by around 10% meaning that around 25% more coal has to be used to produce a unit of electricity. For a gasification power station the penalty is around half of this.

Crucially, the technology for pre-combustion capture is available at commercial scale now. The equipment can be seen operating in Dakota in the US. Coal is gasified, CO_2 is removed from the synthetic gas, piped for 200 miles to oil fields in Canada where it is injected and stored. In this case the commercial rationale is to enhance oil recovery rather than purely to sequester CO_2 and the resultant decarbonised synthetic gas is used to manufacture synthetic natural gas rather than used to produce electricity. However, this plant operates at commercial scale and has been demonstrating capture and the full CCS chain at scale (3Mte CO_2/yr are captured and stored) for more than a decade.

Three Combined Cycle Gas Turbine manufacturers, Siemens, GE and MHI offer suitable gas turbines and the several manufacturers offer the process equipment for the gasification of coal and the separation of CO_2 from the raw synthetic gas. However, whilst all the equipment is available there are a limited number of such coal gasification plants worldwide and hence investors would be exposed to more technical risk if they chose to invest in this plant rather than conventional coal power stations.

3. Barriers to investment in carbon capture

New coal power stations can be built today at commercial scale with pre-combustion CO_2 capture on the complete plant. In the UK at least three such 800MWe stations are at various stages of development. So why are these developments not moving forward? Several of the large utilities have been promoting the continued use of conventional power station technology seeking to leave these power stations unabated until post combustion CO_2 capture solutions are eventually proven and the investment in capture becomes economic.

There are a number of issues but the underlying, root cause is that the capital investment in carbon capture and storage cannot be justified as the value of avoiding emissions is not sufficiently rewarded.

The EU Emissions Trading Scheme requires large scale combustion plant, including all coal fired power stations and other plant within the scheme, to buy certificates allowing them to emit CO_2 from owners of other plant within the scheme that has an excess of certificates. The market price of a certificate depends on the balance between the demand for certificates and their supply. Unfortunately as more certificates have been issued than are required this supply-demand balance has resulted in carbon certificate prices which are too low to justify investment in carbon capture and storage – or indeed in any other low carbon generation option. For example, renewable electricity in the UK is supported by an alternative mechanism, 'ROCs' or renewable obligation certificates. It is not possible to forecast the future price of carbon certificates with any confidence, partially because the scheme has not established a track record which gives traders long-term confidence, but more fundamentally because the process of fixing the rules is a very political process involving all EU member states and there are strong pressures to take a cautious approach.

Given a market framework that provides only weak signals on carbon emissions, utility investors have not been motivated to seriously consider coal with carbon capture. The strategy pursued has been to seek the lowest risk coal plant without capture. Such plant based on conventional boiler combustion technology is available commercially in 800MWe units. There is little technical risk associated with investing in such conventional power station technology. E.on are seeking to build a two unit, 1600MWe, plant at Kingsnorth, RWE have been considering 1600MWe plants at each of Tilbury and Blyth in the North East, with other utilities also considering such plant.

Not unreasonably the alternative of seeking to build coal gasification plants, but without the capture element, has not been preferred. This is because such gasification plant is much less proven for power station applications and the skill and experience base called on differs from that already available in the utilities, who operate conventional coal stations.

Hence the market dictates the response of investors and in the absence of a mechanism that provides 'market pull' for CCS, the preference is for unabated conventional power stations.

4. Development and deployment of CCS

Many ageing power stations must be replaced in the next five years or so, and with suitable policies, coal power stations with CCS could be a significant component of the replacement plant.

The assessment of the cost of electricity from new coal plant with CCS indicates that the level of support required is around half of that provided to offshore wind and to some biomass plants. Thus even at its current stage of development coal CCS provides excellent value for money and the consumer could save money, to the extent that the need for an excessive amount of wind or biomass generation is avoided.

The barrier to progress is the absence of an effective mechanism for rewarding the investment and for the first plants, managing the 'first of a kind' risks. The readiness of the technology is not a primary barrier rather it is the absence of the necessary market pull.

Investors in CCS plant must expect to receive the same risk adjusted returns as they can secure from alternative investments whether in gas CCGT, renewables or nuclear. The technology exists to enable industry to respond.

The above discussion has focussed on new plant, but climate imperatives make it clear that existing fossil fuelled plant must also be abated in due course. The Committee for Climate Change has recommended that the electricity sector is decarbonised by 2030. The post combustion capture technologies described above can be retrofitted to existing plant. However the energy penalty and high capital cost means that this is only likely to be cost effective on the most efficient plant. Repowering options utilising the existing steam turbines as part of a gasification plant may be economic and one such case is already under consideration in the UK on a coal power station.

In industry, CO_2 is already captured and then, because there is no incentive to do otherwise, released to the atmosphere. For example, in ammonia production plants and in gas reforming plant designed to produce hydrogen for industrial use. Other industries, for example the steel industry, are actively considering means for reducing their emissions. In all these cases the real requirement is for policy to focus on the provision of market incentives; industry is good at delivering when the market is clear.

By Peter N Whitton,
Managing Director,
Progressive Energy Ltd

As well as being MD of Progressive Energy, Peter is a board member of CCSA and chairs the incentives working group of the CCSA.
e peter@progressive-energy.com
t +44 (0)1453 824807

Paper 3

Carbon capture and storage – moving to implementation

By Alastair Rennie, Project Director, AMEC

Why bother?

Why do something like carbon capture and storage (CCS)? Certainly not because we want to. It costs money, complicates production and needs political and public support. The only reason we support the rapid introduction of CCS is because we have to.

Climate change is usually the main reason. One way or the other we must reverse the increase of CO_2 in the atmosphere because it increases average temperatures and ocean acidity. Worse, the persistence of CO_2 means cumulative effects. The importance of materially reducing emissions now are twofold; firstly that emissions now are very difficult to offset by emissions later, secondly that system tipping points could occur. We know the modelling of complex systems is difficult but we should at least apply the precautionary principle to the climate change numbers – we use it in planning all the time. The uncertainties of predicting the impact of CO_2 increases have meant we have hoped for the least bad outcomes. However that is not safe, and in any case the costs of action are much less than the consequences of inaction, as the Stern Review and others have shown. CCS is only one of the actions to take, as for example in the IEA's BLUE Map Scenario.

The role of carbon capture, transport network and storage

For the UK and a number of other large countries the importance of CCS is linked to coal combustion because burning coal is their major controllable source of CO_2 and economically important as coal is relatively cheap, abundant and secure. Ideally we should only need one or two generations of coal CCS before it is cheaper to use renewable energy and we may use less as we become more efficient. The present reality is that coal burn is increasing, mostly in developing countries, mostly for electricity, and that such electricity is an important element in poverty reduction however we view the global picture. The only way that the undoubted global negative impact of coal power generation can be alleviated is by adding CCS, despite its additional cost, as without CCS there is no future for coal despite efficiency improvements.

But with CCS there are suddenly new options, not just for coal, but any combustion emitting CO_2, for countries, companies and individuals addressing climate change, energy security and flexibility in their energy use.

What CCS offers is big benefits. A small number of plants can make a material difference. For example, Yorkshire's total CO_2 emissions are 90 million tonnes per year, including transport and homes. There are only 12 sources of over 1 million tonnes per year, mostly power stations but they total 62 million tonnes CO_2 per year. Not only does CCS offer decarbonised electricity, the pre-combustion capture of CO_2 also offers decarbonised hydrogen, which can serve other transport and industrial uses. Hydrogen is important as a replacement for natural gas, but CCS is also important in working to capture emissions from large biomass plants and industrial plants such as steel and cement plants. In general, CCS is not just about coal – it is about de-carbonising any process emitting CO2, including biomass combustion – coal is just relatively easy and is the biggest source.

Accepting that it is an important technique what will it cost? The answer is that though a lot of costs are proven there is still a learning curve to follow. Recent studies that costs for developed nations would lie between onshore and offshore wind, and about the same as nuclear power. Also helpful is that CCS does not compete for the same natural resources as renewables and nuclear power.

It cannot be applied everywhere. Present technology and economics favours larger plant, and the need for secure CO_2 storage is paramount. Fortunately the UK's big CO_2 sources are generally close to offshore storage sites that have been explored for oil and gas. Certainly health and safety of CCS transport and storage is very low given the experience and engineering that can be applied so that the issue of leakage risk is legal and commercial compliance, though the impact of the planning process itself is a major uncertainty in the UK.

Implementing CCS

Where planning can help is in encouraging the clustering of CO_2 capture plant to make best use of transport and storage solutions. It is strongly recommended that clustering be encouraged for this reason and the opportunity for lower cost transport and storage networks. We can also look to sell storage solutions to our European colleagues given that we can provide both pipe and ship access to UK storage.

The UK can use CCS for its own aims, but there maybe international dividends if the UK is timely and decisive in its actions. The first step was climate change targets through to 2050, the second the four demonstrator projects combined with funding aimed at CCS for all large power plant. More specifically we now need to see more articulated detail of the way-markers for CCS such as the following features:

- The demonstrators are for saving CO_2 emissions as well as learning by doing at full scale to reveal and drive down costs.
- The demonstrators are the foundation blocks for the best available technology deployment of CCS from 2020 in lower cost clusters supporting new de-carbonised jobs.
- The role of CCS is actively promoted to the public and in the planning process as a systematic part of the strategy for energy and climate change management.
- The first demonstrator has become mired in procedure. The next three must be judged more commercially on the basis of:
  1. Cost/tonne CO_2 stored
  2. Amount of CO_2 stored
  3. Quickest time to start storing CO_2
  4. Scale and speed of the next CCS projects enabled by the demonstrator.

The Carbon Capture and Storage Association (CCSA) also supports the above demonstration assessment and is keen to see forward looking transport solutions as an outcome of the four demonstrators. There are many distractions from what is the best way for the UK to benefit from CCS. These include the 12-project European technology demonstration programme which seeks technology mixes. This is linked with the allocation of the EU new entrant reserve (NER) within the emissions trading scheme (ETS). Less known is the ratification of the cross boarder transfer of CO_2. In the wider world 2009/2010 the UNFCCC in COP15 in Copenhagen in December is an important milestone in CCS formally becoming part of the international effort to tackle climate change. All these are well and keenly fought in the diplomatic arena but ultimately it is what we decide to do that is the key to getting CCS benefits for the UK. Being overly clever on technology choice is not useful – doing CCS at useful scale quickly is useful.

The politics

Good politics is a real enabler for CCS as there is no commercial driver without political will. Despite UK elections in 2010 the main political parties have broadly similar views because there is common understanding of the seriousness of the issues and of the science. Nevertheless the possibilities for mistakes, miscommunication and mischief abound. There is a huge amount of just hard work in implementing CCS, so we seek open communications, sharing of knowledge and cross party enthusiasm in getting CCS to deliver CO_2 savings, jobs and low cost CCS clusters, starting by 2014 and flourishing by 2020.

By Alastair Rennie, Project Director, AMEC

Alastair is a board member of CCSA, Project Director of Renewables at AMEC and was actively involved in producing Yorkshire Forward's report on CCS 'A Carbon Capture and Storage Network for Yorkshire and Humber.'

e alastair.rennie@amec.com
t +44 (0)1325 744400

Paper 4

Geological storage of carbon dioxide

By Steve Murphy, Director - Projects & CO_2 Storage Operations, CO_2DeepStore Ltd

1. Summary

There are three main types of underground CO_2 store: depleted gas fields, depleted oil fields and saline aquifers.

- Depleted gas fields at low pressure require an engineered solution to enable management of CO_2 from dense phase transport to gas phase in storage during early injection periods.
- Most oil fields have been operated under a strategy of pressure maintenance by water injection. The reservoirs will contain significant amounts of water and be close to the original reservoir pressure. Therefore they will have limited capacity for CO_2 storage and provide less attractive storage locations than pressure depleted gas and gas condensate fields.
- Oil and gas fields are better characterised for capacity and integrity than aquifers and consequently will be lower risk stores, initially.
- Aquifers offer significant long-term storage potential but have the highest capacity uncertainty and evaluation cost. The major storage issue to be resolved is how to handle the long term liability for leakage of CO_2.

2. Attributes of the three types of store

Depleted gas fields

Capacity and integrity

The capacity of a depleted gas field without an active aquifer is straightforward to calculate and should be known with minimal uncertainty. The integrity of a depleted gas field, like that of any CO_2 store, needs careful consideration. Usually significant data will be available as a result of oil and gas activity, from which a detailed technical assessment of storage integrity can be made. Existing well stock in depleted gas fields will require careful assessment as potential leak paths in order to assure their integrity. The evaluation cost to develop a reasonable position of certainty for capacity and integrity for a depleted gas field is likely to be in range £1 million to £10 million depending on the existing data available and the complexity of the field.

Availability/timing

Availability of a field is clearly a field specific issue. However, it is unlikely (although not impossible) that CCS can commence until such time that gas production has ceased. The date of cessation of production (COP) may be uncertain. Facilities, if they are to be re-used, are best transitioned directly from one service to another and therefore require a perfect fit between COP and commencing CCS operations. Where facilities are not to be re-used, there is less of an issue over timing and anytime post COP would be reasonable.

Injection phase behaviour

One of the key issues for CCS in depleted gas fields is the management of CO_2 phase behaviour between dense phase delivery and gas phase in the reservoir. Operations will require a managed phase change to avoid significant thermal effects. Whilst this issue has been identified, there is not yet an engineered solution to address it.

Mature oil field

Capacity and integrity

The CO_2 storage capacity of an oilfield is likely to be more complex than a depleted gas field and result in a larger degree of uncertainty. This is as a result of the fact that the reservoir will remain full of fluids including injection water and residual oil. The amount of space available for CO_2 will then depend on fluid flows, the ability to increase reservoir pressure and field size and compressibility. The data required to perform this capacity assessment will be more readily available than for aquifers, but still carries significant complexity. The integrity of an oilfield, like that of any CO_2 store needs careful consideration. Usually significant data will be available as a result of oil and gas activity, from which a detailed technical assessment of storage integrity can be made. The evaluation cost to develop a reasonable position of certainty for capacity and integrity for a depleted oil field is likely to be in the range of £2 million to £20 million depending on the existing data available and the complexity of the field.

Availability/timing

Availability and timing issues are largely the same as those for depleted gas fields. COP dates are very sensitive to oil price and can vary over periods up to 10 years, as the revenue and cost profiles are nearly parallel.

Enhanced Oil Recovery (EOR) potential

If CO_2 is available then EOR becomes an opportunity for certain oilfields, however CO_2 EOR may not be the preferred technique for tertiary oil recovery in any given field. To date, the economics of CO_2 EOR in the North Sea have proved challenging and no projects have commenced. However, if CO_2 were to be delivered to an oilfield for storage, it may be commercially attractive to consider an EOR project. The availability of such fields for storage would then be dependent on the need, timing and shape of the EOR project. The large offshore investments required for CO_2 EOR mean that certainty is required on CO_2 supply levels needed for effective EOR. This may be challenging with early projects. It is unlikely that CO_2 EOR will lead the development of CCS in the UK North Sea, but that with CCS infrastructure in place and CO_2 available that specific CO_2 EOR projects could become commercial under certain higher oil price scenarios. EOR is generally not a net CO_2 storage technique, when emissions from produced hydrocarbon is considered.

Aquifer

Capacity and integrity
There has been considerable discussion on aquifer storage capacity and its uncertainty in the sector. Detailed study of a particular aquifer, which could include significant dynamic reservoir modelling, would help to establish a clearer capacity estimate. Depending on the data already available on an aquifer, further data acquisition may be required. It is likely that additional rock core samples and downhole data measurements would be required to assess the suitability of an aquifer for storage. Existing data is largely from oil and gas exploration and development activities and aquifer data acquisition was not usually the focus of the work programme.

Availability/timing
Availability and timing issues are dependent upon location. If injection into an aquifer could affect nearby oil or gas production operations then it is likely that injection would not be permitted to start until those fields had ceased producing. Remote aquifers are available for storage once they have been suitably appraised.

Appraisal
The evaluation and appraisal of an aquifer to improve confidence in its capacity and integrity would require a specific work programme. A typical exploration and appraisal programme might include a seismic survey and four wells. Such a programme could cost circa £50 million -£100 million, although if existing data were available costs could be much lower. The evaluation may still not adequately address issues of long term integrity and sustainability of CO_2 injection. This is because the dynamic behaviour of an aquifer will remain uncertain until such time that CO_2 is injected and the pressure response assessed.

3. Regulatory environment

The key elements of policy at the various geographic levels are largely in place and are listed below.

International

- OSPAR (governs north east Atlantic) – CO_2 changes to be ratified
- 1996 London Protocol (governs international waters)

European Union

- CCS Directive issued

United Kingdom

- Energy Act 2008
- Climate Change Act 2008
- Petroleum Act 1989

The CO_2 storage regulations are expected to be in place by 2010. In the UK two organisations have the vast majority of responsibility for CO_2 storage. The Department of Energy and Climate Change will be responsible for managing the regulation of CO_2 storage and licensing storage operations (at this stage only storage in offshore sites is being considered). The Crown Estate has the rights to store CO_2 in the subsurface and will lease these rights to suitably qualified operators.

4. Key issues

- The long term liability for a deemed leak from a CO_2 store is probably the largest issue facing the industry at the current time.
- The effective storage capacity in UK Waters remains subject to a wide range of uncertainty. This is due mainly to uncertainty over the effective storage capacity of aquifers, from incomplete knowledge of aquifer pressure behaviour and if they have closed boundaries.
- Open boundary aquifers or production of water from aquifers could mitigate the capacity downside. Water production is technically feasible but would double the storage element of CCS costs.
- In contrast to CO_2 storage projects, CO_2 EOR projects result in the production of CO_2 along with the oil and water. These CO_2-rich produced fluids are very corrosive and require complex process systems,

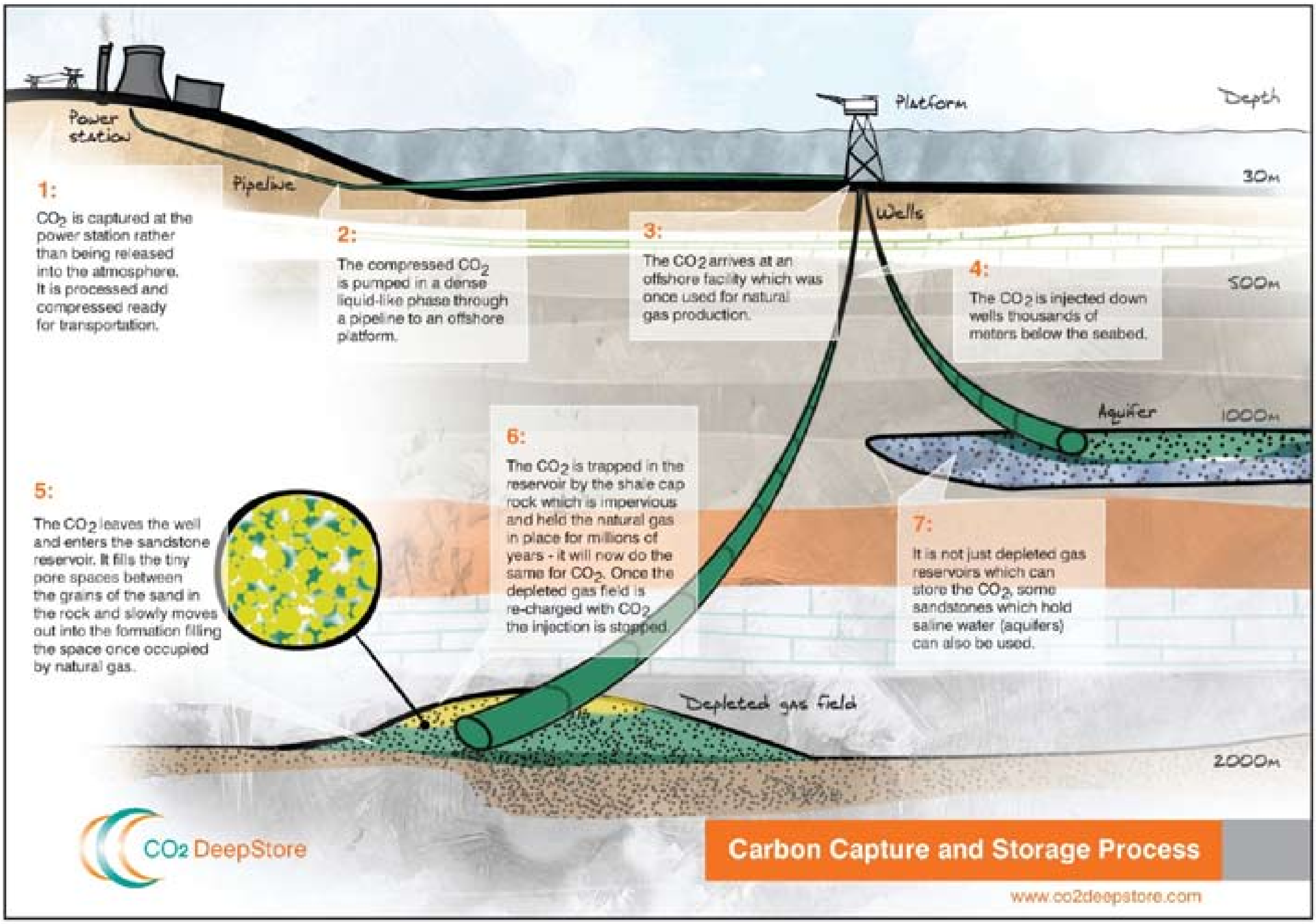
built with corrosion resistant alloys to ensure safe operations. CO_2 EOR projects are thus expected to require significantly more capital investment and operating expense than conventional oil and gas developments or CO_2 storage projects.

- Appraisal and evaluation costs for aquifers are likely to be considerably higher than for better characterised oil & gas fields. Such aquifer appraisal may still not provide sufficient confidence to go ahead with a major project, eg due to uncertainties of pressure behaviour when on injection. One way to gain confidence in an aquifer would be a pilot CO_2 storage project.
- End to end CCS projects will involve complex project integration and require the implementation of complex contractual arrangements and commercial risk balancing between many parties.
- The main risks identified to the widespread implementation of CO_2 storage are;
  - negative public opinion
  - subsurface risk and uncertainty
  - long term storage liabilities
  - regulatory arrangements
  - loss of political support for CCS
  - aquifer appraisal and performance
  - waiting for EOR on oil fields
  - uncertainty of dates of cessation of production on hydrocarbon fields
  - pessimistic views on the long term EU Carbon Allowance and electricity prices
  - CCS not being commercially viable
  - Political and public support is key to moving forwards

By Steve Murphy,
Director - Projects & CO_2 Storage Operations,
CO_2DeepStore Ltd

Steve is focused on delivering enterprise value through CO_2 storage projects. Steve has over 23 years experience of capital investments, asset A&D and programme management with Chevron, Baker Hughes and Helix RDS. He brings expertise in commercial evaluations and project delivery, most recently this resulted in a significant premium being added to the sale value of Helix RDS. Prior to co-founding CO_2Deep-Store, Steve was managing a gas field and a new field development in the UK sector. He is currently serving as CO_2DeepStore's Finance Manager.

e steve.murphy@co2deepstore.com
t +44 (0)1224 224472


Power station
Pipeline
Platform
Depth
30m
Wells
500m
1000m
2000m
Aquifer
Depleted gas field
1:
CO_2 is captured at the power station rather than being released into the atmosphere. It is processed and compressed ready for transportation.
2:
The compressed CO_2 is pumped in a dense liquid-like phase through a pipeline to an offshore platform.
3:
The CO_2 arrives at an offshore facility which was once used for natural gas production.
4:
The CO_2 is injected down wells thousands of meters below the seabed.
5:
The CO_2 leaves the well and enters the sandstone reservoir. It fills the tiny pore spaces between the grains of the sand in the rock and slowly moves out into the formation filling the space once occupied by natural gas.
6:
The CO_2 is trapped in the reservoir by the shale cap rock which is impervious and held the natural gas in place for millions of years - it will now do the same for CO_2. Once the depleted gas field is re-charged with CO_2 the injection is stopped.
7:
It is not just depleted gas reservoirs which can store the CO_2, some sandstones which hold saline water (aquifers) can also be used.
CO2 DeepStore
Carbon Capture and Storage Process
www.co2deepstore.com

Paper 5

Winners, losers, China, NPV and self-service check-outs: The role of policy in carbon capture and storage investment decisions

By Ian Temperton, Climate Change Capital

Capital is indifferent

I have been asked to write about the financing of carbon capture and storage (CCS). Many readers will probably believe that this will therefore be an article about numbers, clever structures and complex ways to arrange for money to flow to CCS. It is not. Instead I am going to focus on the investment decisions for CCS projects and the people who make those decisions.

At Climate Change Capital (CCC) we are particularly focused on investment decisions which are made in response to climate change policy. We believe that capital is indifferent, and hence that in order for funds to flow to climate change related investments, decisions must be made in as rigorous and robust way, as for any other financial undertaking.

People however are not indifferent, and in our attempt to "Create wealth worth having" we make it our particular mission to contribute to the creation of the circumstances in which we, our clients, and others, can make more, bigger and better investment decisions which contribute towards the prevention of dangerous climate change.

Making investment decisions

The investment decision is the process by which a collection of human beings, constituted usually as a Board of Directors or an Investment Committee, decides to allocate capital, the stewardship of which they have been entrusted with, towards the pursuit of a new undertaking. That collection of human beings is usually in various legal, economic and moral ways held accountable for that decision.

The text books will tell you that investment decisions are made when something called the Net Present Value (NPV) of the investment is positive. This is true. However, there is far more to an investment decision than that. In fact, in real life no investment decision ever goes to a decision body without showing a positive NPV, so the text book is relatively useless in this regard.

Real investment decisions are made when the collection of individuals comprising the decision body are convinced, usually by a group of people working for them (and perhaps their advisors), that, as well as being positive NPV, the new undertaking is well-informed, consistent with their strategy, based on robust assumptions and information, and that they have confidence in the successful execution of the investment.

All in it together?

One of the more standard strategies proposed by advisors in the energy market is for companies to be more like each other. "He has more wind farms than you; hence you should buy some wind farms", for instance. While it is a lazy pitch, it is grounded in some logic. In the production of an undifferentiated commodity (electricity), where many of the risks come from external shocks, regulation and regulatory change, it makes sense to be broadly aligned with your competitors. That way everyone is aligned in resisting negative shocks and no-one's relative competitive position is harmed if such changes do occur.

This is perfectly aligned with CCS policy.

The world needs the rapid global adoption of CCS technology if we are to deal with coal emissions, and hence we want every utility and energy company making similar investment decisions for CCS as soon as we can.

Winner takes all?

Now, the vogue method for the allocation of public support for CCS around the world is competition. In fact in the UK example it is the competitive procurement of a CCS power station of a technology pre-selected by the UK government.

That must be good, you may say. Competitions will create winners, and the fight against climate change needs winners. No. A single competition creates a winner, and many losers. This is the problem.

In the investment decision process people need to convince their bosses to allow them to develop the investment case. This costs money and time, and requires a substantial investment of the personal credibility of the individuals involved. Hence creating the circumstances in which such people lose more than they win does not create positive momentum in the industry.

Despite leading the diplomatic and political debate on the global adoption of CCS, in the UK domestic CCS policy has managed to lay waste to the aspirations and endeavours of many of those trying to drive investment decisions in this area.

First was the incident with a large proposed CCS project in Scotland. None of us will ever know quite what happened, but it is clear that lots of money was spent on the project and eventually it was stopped. Next came pre-selecting a certain technology for the UK (post-combustion capture) meaning that the work of all those developing alternative technologies (especially pre-combustion) was written-off. Next came the idea of a competition which means that of nine original entrants all but three have already had to tell the boss that it was a waste of time and money, and finally we will create two more failures, in selecting the supposed winner.

Note that the prize for winning is to be an outlier amongst one's peers investing in a project using a technology that one did not freely choose.

Learning by doing

The logic behind the carnage is that we have to do one first in order to "learn by doing". To understand this, accompany me to the self service check-out in my local DIY store this weekend.

You will marvel at some bright young professional's inability to scan their shopping and put their credit card in the right slot. This despite the fact that they are likely to have a more highly paid weekday job than the young shop assistants who seem able to use the machines while hardly looking at them. How so?

Quite simple, our south London professional buying three new plant pots is "learning by doing". As the use of the check-out is a small, one-off transaction with limited consequences of failure (ignoring the externality created for those of us stood in the queue behind them), he or she has decided not to undertake any learning ahead of the decision to use the machine. The teenage shop-assistants on the other hand clearly have received both training and practice.

Despite what one might have observed in the financial markets of late, Boards and Investment Committees will simply not allow their organisations to learn on the job with potentially hundreds of millions of pounds of investment. They would be derelict in their duty if they did. In contrast to our weekend DIY enthusiast, they will insist on vast amounts of engineering and financial assessment ahead of time, and hence in the case of a CCS project, if most of what has to be learned about the investment has not been learned ahead of the investment decision then the decision simply won't be made.

China and the lost generation

Another reason for many policy decisions is what has become one of the most quoted statistics in climate change. That China builds about 1GW of new coal power generation every week. That is a new UK electricity sector powered only by coal every year. Hence we apparently have to teach China how to build clean coal power stations.

An alternative conclusion is that China knows how to build coal-fired power stations. In fact as I write this on a Monday, they will have built a new power station the size of the UK CCS demonstration project by some time on Tuesday or early Wednesday (I am never sure if the 1GW statistic includes them working the weekends or not). The UK, by contrast, has not seen an investment in a new coal-fired power station for a generation.

The challenge for the UK is not to provide solutions for China; it is to replace a missing generation of people who know how to make large-scale power generation investments, and to bear the cost of CCS in our own economy, so that China can then deploy its vast resources to do the same sooner than it perhaps otherwise would.

It is a wider topic than this article can deal with, but the issue of lack of experience and recent precedent in large-scale power sector investment is not unique to coal.

Back to NPV

Unlike the Chinese, the Boards and Investment Committees of the energy sector are understandably confused about investment decisions in new coal-fired power stations.

They know that to build a new unabated plant in the western world is utterly inconsistent with the emissions reduction requirements which are ever more solidly embedded in energy policy. However the explicit price for carbon emissions as priced in the European emissions trading scheme is insufficient to pay the additional costs of CCS, and hence the spreadsheet will not show a positive NPV without additional policy support. (We think early CCS projects need around 50 Euros / tonne of CO_2 stored in the ground over the life of the project).

However if they begin to invest in developing CCS, the evidence is that they are more likely to see their investment written-off by policy than supported by it.

There must be four

Governments also seem to learn by doing. Hence around the budget of 2009 the UK Government announced plans for four CCS plants. Actually it announced the existing CCS competition, one more, and then maybe a couple more in the future depending how the first two go.

It must be four, and I can explain why.

Firstly, this will tip the balance so a majority, if not all, of the good projects with substantial investment behind them in the UK can be winners. Secondly, it will put a project at most of the logical hubs in the UK, and create the potential for clusters which will stimulate and facilitate new investment decisions in further CCS development in those areas (laying the ground for the next generation of winners). Thirdly, it will create sufficient activity to both mobilise a supply chain and to ensure the majority of the energy industry can participate in the learning and skills development (which will occur before the investment decision, and which they need in order to continue to be winners in this area). Fourthly, three more will create the opportunity to learn about CCS, because unfortunately the first competition is going to teach us more about policy design than it will about CCS.

Policy design in this area is not easy. If we manage to deliver the millions of investment decisions needed in emissions abatement and avoidance in the coming decades, we will, in the process, develop new theories and frameworks on the interaction of policy making with the process of making investment decisions.

We have learned that support for the next three plants (and those beyond) should not be awarded by government procurement and competition, but instead on a set of broad criteria, leaving decisions and risks on technology and project execution in the hands of those in the private sector most able to manage them.

The rush to make quick political decisions in CCS policy has meant that policy-makers have approached the issue of incentives and policy objectives in much the same way as a south London professional approaches the self-service desk at a DIY store. Little investment has been made ahead of time, in understanding the overall fit of the policy with the desired outcome.

There is evidence that policy-makers are starting to learn too, and it is imperative that the simple human elements of the investment decision start to be incorporated into the policy-making process and that CCS policy picks a few less winners while creating a lot more.

We all need them.

By Ian Temperton
Climate Change Capital

Ian is the head of the Advisory team at Climate Change Capital (CCC). He is a member of the Investment Committee for CCC's carbon investment funds. He has a degree in civil engineering and was a QUEST Scholar of ICE.
e itemperton@c-c-capital.com
t +44 (0)20 7939 5116

Paper 6

Carbon capture and storage regulation and performance standards: the potential to drive growth, exports and jobs

By Andrew Raingold, Deputy Director, Aldersgate Group

The global "roll for coal" shows little sign of waning. Driven by an unrelenting thirst for energy and concerns over security of supply, this cheap and plentiful energy source lies at the very heart of international growth strategies. Coal supplies about half of the total power generation in the United States, 70% in China and there are plans for over 70 new coal-power stations across the EU.

At the same time, the scientific community is increasingly alarmed that global greenhouse gas emissions are rising much faster than predicted and the forecasted economic and social costs are even more severe. To mitigate these risks, emissions from developed countries must be reduced rapidly, with the almost full decarbonisation of the power sector by 2030.

Policy makers believe that carbon capture and storage (CCS) will be essential to meet this objective. The International Energy Agency estimate that the costs of tackling climate change could increase by 70% without it. It also needs to be developed urgently if it is to play a significant role in a cost-effective global abatement framework. With Europeans keen to take the mantle, it hopes to ensure 12 demonstration projects are built quickly, a second round of semi-commercial projects come on line before 2020 and there is full scale commercial deployment post-2020. To be successful, the EU should build on its current policy framework to implement a rigorous emissions performance standard, as well as develop its regulatory approach to transportation and storage.

The importance of regulation cannot be understated. CCS will always be more expensive than conventional fossil fuel generation as it involves additional industrial processes. Therefore, its effective deployment depends on the policy framework set by governments. In the long-term, it is expected that this will be met entirely by a sufficiently high and stable carbon price (optimists predict 30 euros a tonne) under the EU Emissions Trading Scheme (EU ETS) or worldwide trading scheme. In the meantime, governments have a key role to play to demonstrate its economic and technological feasibility, help bring costs down and ensure that economies do not "lock in" to high carbon power generation for years to come.

For those countries that lead the way, better regulation has the potential to be a major source of competitive advantage. With an eye on future Chinese and Indian markets, incentivising domestic industry to develop the valuable skills and know-how could lead to vast export growth potential. More widely, setting high environmental standards can stimulate dynamic, world leading industries. Such a view is put forward assertively by the Aldersgate Group, a high level coalition of progressive businesses, MPs and third sector organisations of which the Institution of Civil Engineers is a member.

In regard to CCS, the UK has a number of competitive strengths, ranging from technical expertise to a large number of suitable storage sites in depleted North Sea oil fields (with potential capacity to hold over 1000 years of UK carbon emissions). To take full advantage of these strengths, a more robust regulatory approach is required.

Progress was made in December 2008 when the European Parliament endorsed its Climate Package, and made three significant announcements on CCS. Firstly, the EU agreed a directive on geological storage, providing much needed regulatory certainty. It outlines a risk management framework for regulating the environmentally safe storage of carbon dioxide, including provisions enabling the long-term responsibility for storage sites to be handed over to national competent authorities. Although further development is required, this is a good base to establish guidelines and standards.

Secondly, the EU allocated 300 million emission allowances (with an estimated value of nine billion Euros) to fund 12 large-scale CCS demonstration plants by 2015. Projects will have to pass stringent criteria and the company bears the technical risks of project performance (with payment relating to the amount of carbon successfully stored).

Thirdly, and most controversially, the EU required all new coal plants to be "capture ready". This is an almost inconsequential concept, meaning that there is merely enough space on site to accommodate CCS equipment and transport the abated carbon to a suitable storage site. Such an ambiguous capture-readiness requirement risks helping to justify a new suite of unabated coal plants across Europe without assurances that any carbon produced will be captured and risk locking the EU into a high emissions trajectory.

The UK built on these European developments when it launched its "no coal without CCS" policy the day after the 2009 Budget. It ensures that at least 300 MW of net output must be captured and stored from new coal plants and the full scale retrofit of CCS within five years of the technology being independently judged as technically and commercially proven. Complementary declarations of world leadership are open to question given that only around one-quarter to one-fifth of total emissions from a new plant will be captured and the lack of an adequate exit strategy if CCS does not become feasible when anticipated.

Although welcome, this policy does not go far enough. Kingsnorth, in particular, has caught the public's imagination as a symbol of government hypocrisy over climate change and is under acute media scrutiny. By capturing only 300MW of carbon, Kingsnorth would still have higher emissions than an unabated gas plant (and E:ON have now delayed its plans for at least another three years).

To succeed in its ambition to be a world leader, the UK should adopt an ambitious emissions performance standard, based on the California model. This stipulates that no new power plant can have greater emissions than a combined cycle gas turbine plant. It provides a "long, loud and legal" signal in the transition to low carbon, reinforced by the prevention of Californians to import power from coal-fired power plants located out-of-state.

A blueprint for how this might work at a federal level in the United States was outlined by the United States Climate Action Partnership, a coalition of businesses and environmental groups. Its sets out a three stage process, namely (1) early demonstration funded by emission allowances; (2) a rising emissions performance standard to 2020 which will be reviewed every five years; and (3) a rising carbon price so that the carbon market would provide adequate incentives in the long-term. A similar framework should be adopted by the EU but it refuses to assess whether such a performance standard is "needed and practical" until 2015.

The Conservatives support the implementation of an emissions performance standard in the UK but only at a level of 500g/kwh. Applying this to Kingsnorth, this would mean that 600MW of the overall 1600 MW capacity would be abated. While this would double the proposed amount under the current government policy, the plant might still emit over four million tonnes of CO_2 every year of its 50-year life span. To be effective, there must be a clear framework for ratching up the performance standard as the technology matures.

A much more comprehensive strategy has been put forward by a group of leading NGOs, including Aldersgate Group members WWF, Friends of the Earth and RSPB, in a joint statement that was published in June. It suggests a minimum UK standard of 300g/kWh, which is comparable to an efficient gas-fired power station that makes use of waste heat. By 2025, this would rise to 100g/kWh, ensuring that the carbon intensity in the power sector reduces at least in line with the recommendations from the Committee on Climate Change.

Regulation also needs to be put in place for the supporting infrastructure, including new carbon deposit networks and pipelines. The EU directive on geological storage is a good foundation but further issues must be addressed immediately, such as the size of the pipe networks to ensure capacity is sufficient to meet future demand without modification. The pipelines represent significant planning challenges, while open access arrangements and potential security concerns must be addressed.

Perhaps the most significant barrier of all is winning public acceptance. In Germany, none of the carbon captured from the Schwarze Pumpe power station near Berlin has yet been stored underground due to regulatory delays and regional objections. Farmers, in particular, have opposed to carbon being stored hundreds of metres under their fields despite no credible evidence that it presents a hazard. When pipe networks are drawn up in the UK, there is a significant risk of a similar public backlash unless a strong case is made and awareness improved.

All these issues must be resolved urgently and cross-sector coordination is vital. For this reason, the Green Alliance, for one, are coordinating industry, government, NGOs and academia in an attempt to broker agreement on key issues. Arguably the most critical is the need for a stringent emissions performance standard and this must be supplemented with a clear regulatory framework and strengthened public support. If the UK gets this right, it could make a significant contribution to global emissions abatement and create high quality jobs and export opportunities in the process.

By Andrew Raingold
Deputy Director
Aldersgate Group

The Aldersgate Group is a coalition of businesses, environmental groups and individuals that provide the economic case for high environmental standards.
For more information, visit www.aldersgategroup.org.uk.

e andrew.raingold@aldersgategroup.org.uk
t +44 (0)20 7863 8712

ICE Energy Panel conclusions

Carbon capture and storage – time to deliver

In this booklet ICE has brought together six leading CCS experts to explore what steps need to be taken to deliver CCS in the UK.

To make the most of this opportunity ICE believes government needs to provide the strategic overview and supportive environment necessary to progress without delay. A regulatory framework must be put in place to support the demonstration programme, which will facilitate the commercial scale development of CCS.

It is essential that the UK acts now in order that carbon reductions are achieved earlier and the UK fully benefits from the commercialisation of CCS.

The potential role of CCS

The UK Government and the Committee on Climate Change give carbon capture and storage (CCS) a central role in achieving the reductions in emissions required to combat Climate Change. The UK has made a unilateral commitment to an 80% reduction by 2050 against 1990 levels. CCS on a commercial scale can play a key role in delivering these stretching targets.

The UK, with its world class engineering base, is well placed to develop technology suitable for new and existing carbon emitting power stations around the globe. Industry and government should therefore be viewing CCS as an export opportunity and must ensure that technology developed in the UK is applicable overseas.

Implications of CCS on electricity generation and emissions – cleaner not carbon free

The capture of carbon during electricity generation offers an opportunity to significantly reduce UK carbon emissions. By capturing carbon, it will be possible to reduce the associated carbon dioxide emissions by 80-90%. There will also be a need for additional energy for the transfer of CO_2 to a storage location. Thus, by capturing carbon more energy generation will need to take place, estimated at 5-10% of the plant's electricity export, thereby burning more hydrocarbons (up to 25%).

Engineers and governments must be open with the public and make it clear that CCS will enable cleaner but not carbon free coal and gas fired power stations. To promote an integrated approach to carbon management, the assessment of CCS must include the embodied carbon from the construction process for each element.

Challenge and opportunity

A fully operational, commercial scale CCS facility will require the bringing together of technologies to capture, transfer and store carbon.

Individual aspects of CCS have been proven; working examples of the three core elements exist in some form in Japan, USA and in Europe, although not at the scale required for major power stations.

In the UK it is foreseeable that utilities will seek to construct a number of new coal fired power stations in the short to medium term. This presents the engineering community with the opportunity to make the UK a world leader in CCS technology. The engineering base has the skills to grapple with the challenges thrown up by the different technologies currently under trial in Britain and around the world. However government must play its role by providing a strategic policy framework that provides the certainty required for industry to be able to make realistic decisions.

Preparing for up-scaling will require detailed planning which must start now. Many of the skills that will be required for the roll out of CCS already exist within the engineering and construction industries – but not necessarily in the numbers required. Government, industry, academia, Sector Skills Councils and professional bodies will all need to co-operate to tackle this issue.

Moving forward – making the most of the current trials

Four CCS demonstration projects have been announced by government and will be in operation by 2015 onwards. Each will lead to development of real infrastructure on the ground. The ultimate tests for these trial projects will be that:

- CCS is shown to be technically efficient in reducing CO_2 emissions
- CCS is shown to be affordable, compared to other low carbon technologies

The UK is committed to a radical reduction in CO_2 emissions and faces a genuine threat of a shortfall of supply. Delivering lower emitting new generating capacity is therefore a matter of urgency. To avoid unnecessary delay, we should plan now for:

- timely and effective tests of the demonstration project outcomes, to give early feedback, and
- the next steps that would follow a successful outcome of the demonstration projects, integrating these into a programme for up scaling CCS

The case for clustering

Clustering of electricity generation and CCS infrastructure has the potential to reduce the energy required to transport carbon to storage sites and this should be strongly encouraged in the CCS policy package.

However, government should not be prescriptive on the location of future electricity generation as this could preclude novel yet viable opportunities driven by wider factors.

The case for a strategic level lead from government

At present the most appropriate first choices for storage sites for captured carbon are depleted North Sea oil and gas fields. The wide geographical distribution of power stations will create a need for many miles of pipeline to move carbon to its final storage site. Other options, such as saline aquifers, require further technical appraisal.

CCS therefore requires a significant new national infrastructure network entailing a major investment in facilities and pipelines. This network will cross the boundaries of many local planning authorities adding to complexity and risk for developers. To facilitate this investment, government must provide strategic level clarity and reduce uncertainty.

In the first instance government should commit to produce a National Policy Statement (NPS) on carbon capture and storage alongside those being produced for nuclear, gas storage, electricity networks, renewables and fossil fuel power stations.

To increase its effectiveness the NPS should be backed by a roadmap for the development of CCS in the UK with deadlines for the completion of government's actions around planning, licensing, regulatory regime et al. Given the potential of CCS to meeting our emissions targets, this roadmap should be owned by a senior Minister charged with making regular reports to parliament as a part of the UK energy mix.

Standards and regulation

As part of this roadmap there are a number of major issues that will need to be resolved around standards and regulation. These include:

- Management of agreements on access to the CCS network by emitters
- Agree common technical standards following demostrations and innovations for each of the three elements
- Procedures for prioritising access to the network
- Identification of a body responsible for licensing, monitoring and verification of storage
- Ownership rights and liabilities for stored minerals and hydrocarbons
- Definition and administration of responsibilities and liabilities

Finance

There is no stand alone financial reason for the development of CCS. It is simply a mechanism to reduce carbon emissions. Therefore, for CCS to be rolled out at scale clarity will be required on how it will be turned into an investment that makes economic sense.

Options include:

- relying on the EU Emissions Trading Scheme to deliver a sufficiently high price of carbon, or introducing some form of price support
- including investment in CCS infrastructure in the Regulatory Asset Base of energy utilities and
- introducing a Climate Change Obligation on the model of the Renewables Obligation

Whatever option is selected, government and industry will need to be open that the demonstration of CCS will push up energy prices for consumers. Ultimately, the mix of different low carbon technologies in energy supply will depend on their relative costs, taking account the value of the carbon avoided. A mature CCS technology will need to compete on its merits.

Conclusion

The major political parties in the UK have all committed in principle to the development of CCS. Politicians must now move beyond rhetoric and provide a stable, strategic context within which companies, organisations and engineers can assess and define the practical contribution of CCS. The first step should be a National Policy Statement for CCS based on the current demonstration programme. Ultimately government needs to set out a clear roadmap for development, backed up by strong ministerial accountability.

With this framework in place, government should resist the temptation to pick winners or to micromanage technical development. The UK has a world class engineering base and it should be given the freedom to develop solutions to the challenges thrown up by commercial scale CCS.

Perhaps most importantly of all we need to acknowledge the urgency of the need to reduce our emissions and secure the UK's energy supplies. Government should show commitment by planning now for the next steps after CCS demonstration projects are completed as part of the programme to 2050 for transition to a low carbon economy.

Ultimately, CCS will have to be both technically and economically feasible if it is to contribute to decarbonisation, alongside other low carbon technologies. The overarching objective is to determine as quickly as possible whether CCS is feasible and – if it is – to proceed without delay to full implementation.

Institution of Civil Engineers

Institution of Civil Engineers
One Great George Street
Westminster
London SW1P 3AA

t +44 (0)20 7222 7722
f +44 (0)20 7222 7500
ice.org.uk

Registered charity number 210252.
Charity registered in Scotland number SC038629.

Design by ICE Marketing October 2009
Printed on paper made from sustainable resources.