



HM TREASURY – CARBON CAPTURE AND STORAGE
A CONSULTATION ON BARRIERS TO COMMERCIAL DEPLOYMENT
ROYAL DUTCH SHELL plc – May 2006

We welcome this consultation on the barriers to commercial deployment of carbon capture and storage.

The World Business Council for Sustainable Development's "Pathways to 2050: Energy and Climate Change" [\[1\]](#) looks at the changes needed to begin to stabilise CO₂ concentrations in the atmosphere at no more than 550 ppm. This will require large-scale deployment of a wide range of technologies with high investment and complex choices that will completely transform energy production and use. Energy flows through the economy give an insight into the key areas that must be tackled and five megatrends emerge that all have a major role to play in reshaping our energy systems, either as energy users, emitters, or both. These are power generation, industry and manufacturing, mobility, buildings and consumer choices.

The report indicates that fossil fuels are likely to play a major role in the primary energy mix at least until mid-century when the primary energy mix could comprise 60% fossil fuels, 10% nuclear, 10% biomass and 20% renewables. Thus, while it is important to develop technologies that are not dependent on fossil fuels, this should not detract from the considerable importance of producing and consuming the necessary fossil fuels in a clean and efficient way, while using carbon capture and storage technologies of various kinds to tackle climate change.

Shell recognises that a major change in energy infrastructure and the way energy is used will be needed over the coming decades if society is going to address climate change. This is a global problem that needs global solutions. No single solution will deliver this major change.

The key points from our submission are:

- **CCS is essential in tackling climate change.**
- **Time is of the essence and development and deployment need to start now.**
- **We welcome the opportunity to participate in the development of the CCS framework and would like to discuss these issues with the UK Government.**
- **A regulatory framework needs to be developed that deals with long-term liabilities for CO₂ storage.**
- **CCS projects will require high up front investments and Government support will be required to enable such projects to climb the learning curve.**
- **The EU ETS and CDM could provide vehicles for incentivising potential investments in CCS.**
- **Public acceptance of CCS in the UK has not yet been established and is an important area that needs to be addressed.**
- **An offshore infrastructure for CCS in the North Sea built on a point-to-point basis will not deliver the economies of scale that will enable large-scale CCS implementation – there is a need for a general infrastructure. This will require an alliance-based approach with Government involvement to explore the options for how the infrastructure could be developed.**
- **Appropriate international agreements will be needed to make sure that the North Sea could be treated as a whole.**
- **Establishing CO₂ value chains will be technologically and commercially challenging.**
- **Focus should be put on the necessary research and development of all the technology steps along the chain.**
- **International standards will be required for coal fired power plants to ensure that there is a level playing field.**



We support and are involved in the development and deployment of CCS as a safe, reliable and ultimately cost-effective mechanism to reduce industrial CO₂ emissions. Details of some of our current activities are provided as an Appendix.

In addition to responding to the specific questions under the six themes below, we draw attention to the IPCC "Special Report on Carbon Dioxide Capture and Storage" published in September 2005. Our Principal Scientist for CO₂ Mitigation was one of the lead authors of this report under the auspices of Working Group III of the IPCC. A copy of the report is attached to this submission as we have referred to it at various points in the text.

1. POTENTIAL CARBON REDUCTIONS

Q. What CO₂ savings could be delivered by CCS and how do these savings vary between different options for deployment, different fuels and different kinds of technology at each stage of the CCS process? Can the life-cycle CO₂ savings be estimated comparably with those of other technologies?

CO₂ Savings

We consider that Section 3 starting on page 21 of the IPCC Technical Summary Ref [2] provides a comprehensive and up-to-date summary of the CO₂ savings that can be delivered by different carbon capture technologies and with different primary fuels.

It is important to note that there are considerable differences in the quantities of CO₂ emitted by gas and coal fired power stations of the same generating capacity. From Table TS.3 on page 25 of the IPCC Technical Summary Ref [2] it can be seen that the CO₂ emissions' flow rate from coal-fired power stations is approximately twice that of the equivalent CCGT. So, whilst the percentage of CO₂ reductions given in the table is consistently between 81 and 91% for all fuel types, this represents very different reductions in terms of the quantity of CO₂.

This reflects the fact that natural gas is a relatively clean fuel compared to coal. Applying CCS to coal fired power generation avoids approximately twice the quantity of CO₂ emissions per unit of power delivered compared to applying CCS to natural gas fired power stations.

The programme over the coming decade for new/replacement power station construction in the UK was summarised by the Carbon Capture and Storage Association (of which Shell is a member) in their submission to the recent Energy Review:

"It is expected that, by 2020 over 20,000 MW of new plant will need to be built in order to meet new demand plus the replacement of closed plant. This is the equivalent of about 30% of existing capacity, and would generate about 140 TWh.

It is estimated that about an additional 40 TWh could be generated by new renewable energy sources, leaving the remainder to be achieved by either new nuclear or fossil power plant.

...

In the absence of a large scale nuclear new build programme, and with the penetration of renewables into the electricity market likely to be less than 20% by 2020, there is likely to be the need for at least 250 TWh of fossil power plant generation.

CO₂ emissions associated with 250 TWh fossil plant output would be in the range 100 to 195 Mt CO₂ (an all gas – to an all coal portfolio). If CCS technology were applied to all such fossil power plant, then the net CO₂ annual savings would be between about 90 and 170 Mt CO₂."

The total UK emissions are currently 560 MMTA CO₂¹. In the extreme case in which CCS is applied to all fossil fuel power generation CCS has the potential to reduce UK total emissions by between 15 and 30%, depending on the ultimate fuel mix.

So, the simultaneous availability of CO₂ capture technology with the programme of construction in the power industry suggests a significant potential opportunity to apply CCS in the UK.

However, this potential opportunity must be considered in the context of the challenges associated with the options for deployment of complete carbon capture *and storage* projects.

¹ Provisional estimate for 2005 based on Net CO₂ Emissions of 153.0 MMTA CO₂ as C published on <http://www.defra.gov.uk/news/2006/060330a.htm>



Options for deployment of CCS

Two clear deployment options are available:

- (1) The construction of a small number of demonstration projects with the objective of developing capability and technology that can be utilised to exploit global markets for CCS technology and that, as a by-product, have a modest impact on UK emissions reduction targets; or
- (2) The construction of CCS infrastructure suitable for achieving significant reductions in CO₂ emissions (say at least 10% of current total emissions, or one-third of the “extreme case” target stated above) and that, as a by-product, develop capability and technology that can be utilised to exploit global markets.

Given the vital importance of CO₂ emissions reductions and the Government’s stated objectives to achieve this, we focus our response on option (2).

Having identified that the theoretical potential for CO₂ capture is considerable, we now turn to what could be achieved by an ambitious but practicable programme of CCS investment. To do so we will consider all stages in the CCS “value chain” – capture, transportation and storage. We will start our treatment at the storage end of the pipe, specifically with an assessment of the demand for CO₂ that would result from a significant uptake of CO₂ EOR in the UKCS.

CO₂ Demand from EOR on the UKCS

The theoretical potential for incremental hydrocarbon recovery from the UKCS using CO₂ has been variously estimated over recent years. For example a recent study carried out by the European Commission DG Joint Research Centre Institute for Energy² provides the following estimate (Figure 2.6 from the report):

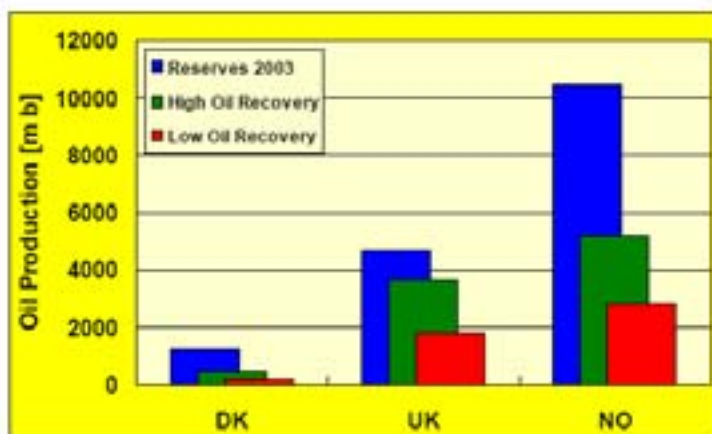


Figure 2.6: Estimated maximum potential for additional oil production by applying CO₂-EOR techniques in the UK, Norwegian and Danish oil fields of the North Sea under different assumptions for oil recovery rates.

Taking the high (3500 MMbbls for the UK) and low (2000 MMbbls for the UK) oil recovery scenarios presented in this report and making the assumptions that:

- All oil recovery is achieved through miscible flood with a recovery rate of 1bbl per 0.33Te/CO₂; and
- Enhanced oil recovery is achieved over a 30-year period.

The requirement for CO₂ can be roughly calculated as:

$$\text{High Annual CO}_2 \text{ demand} = (3500 \times 10^6) / 30 \text{ yrs} \times 0.33 = 38.5 \text{ MMTA}$$

² Report EUR 21895 EN “Enhanced Oil Recovery Using Carbon Dioxide in the European Energy System” by E. Tzimas, A. Georgakaki, C. Garcia Cortes and S.D. Peteves, December 2005.



Low Annual CO₂ demand = $(2000 \times 10^6)/30\text{yrs} \times 0.33 = 22 \text{ MMTA}$

It should be noted that, especially for large highly depleted fields, immiscible flood is likely to be necessary. The recovery factor per tonne of CO₂ injected is much lower in these cases, meaning that for each barrel of oil recovered about 1 tonne of CO₂ is required. This will increase the estimates above. **So, in “order of magnitude” terms maximum exploitation of CO₂ EOR for the UK will demand between 30 and 60 MMTA of CO₂³. This implies that between 5 and 10% of current total UK CO₂ emissions (taken as the current 560 MMTA) could be diverted to UKCS CO₂ EOR schemes.**

CO₂ Supply for CO₂ EOR from UK CO₂ sources

A 1GW Integrated Gasification Combined Cycle (IGCC) power station fitted with pre-combustion CO₂ capture will deliver approximately 6 MMTA of CO₂.

So, to deliver the CO₂ required for large scale EOR exploitation on the UKCS implies the installation, in order of magnitude terms, of a range of (30 MMTA/6 MMTA =) 5 x 1GW power stations and 10 x 1 GW power stations⁴.

Given that a number of proposed power stations are in the 400MW to 1GW range, the total number of sources that will be required to provide CO₂ for EOR could be in the range of 8 to 15.

Potential Carbon Reduction in Summary

Taking the theoretical potentials, orders of magnitude and assumptions stated above, the following conclusions could be drawn:

- **Large scale uptake of CO₂ EOR could utilise between 30 and 60 MMTA of CO₂.**
- **This would require capture of CO₂ from between 8 and 15 major emitters. If these are all power stations, they would be delivering between 5 and 10GW of electrical power and would represent between 25% and 50% of all new build generating capacity to built by 2020.**
- **This project would lead to a reduction in total UK CO₂ emissions of between 5 and 10% when the CCS scheme is completed and running at full capacity. Averaged over the life of the project, the quantities would be at the lower end of this range.**

If EOR use of CO₂ was to be replaced (partially or completely) by pure storage the theoretical storage potential for carbon reduction is very much greater. However, we suggest that the order of magnitude for carbon reduction summarised above (5 to 10%) represents an ambitious but practicable target based on present knowledge.

We should now like to outline some of the challenges that would be encountered in achieving this ambitious target. These are, to a large extent, dominated by the considerable infrastructure that would need to be installed to make CCS happen.

Implications of Large Scale CCS Deployment (for EOR and pure storage)

- The location of UK sources (principally power stations) onshore and UK sinks offshore implies a significant investment in CO₂ transport infrastructure.
- Fields with high CO₂ EOR potential are located from the southern end of the central North Sea (CNS) – the area of the Ekofisk and Valhall fields – northward, following (approximately) the median line between the UK and Norwegian Continental Shelves, to the mature fields in the northern North Sea (NNS) – Brent, Gullfaks, etc.
- Thus, straight-line distances covered by the CO₂ transport infrastructure will be in the order of 500km (shore to CNS) to 1000km (shore to CNS then north to the NNS).
- It would almost certainly be the case that this infrastructure would be installed in a phased manner, starting at the southern end and moving progressively north.

³ This range is in line with the figures given in Table 4.11 of Report EUR 21895 EN (see footnote 2) taking just the UKCS fields.

⁴ As stated previously, it is expected that 20GW of new power generation capacity will be required by 2020.



- It will be vital to ensure that the initial phase, which is likely to be by far the most expensive phase, of infrastructure does not bottleneck the UK's CCS potential (and indeed the opportunity for incremental recovery). It is vital that economies of scale be realised in this first phase.
- Coordination and planning offshore will be vital because: there are a large number of fields; reservoir characteristics are highly variable; oil and gas exploration and production operations will be continuing; fields have different levels of maturity and different (and dynamic) commercial structures; and facilities have different levels of integrity making them more or less suitable for extended life operation.
- Coordination and planning onshore will be vital because: a number of major sources will need to feed into common infrastructure; these sources will become available over a number of years; and the plant and infrastructure required will involve significant spatial/development planning issues (pipelines carrying CO₂ at above 110 bar).
- That a number of CO₂ sources will feed a common CO₂ transport infrastructure has implications for the selection of locations for carbon capture projects.
- Another significant coordination and planning issue that is often overlooked is the natural inconsistency between CO₂ supply and demand in CCS+CO₂ EOR schemes. Very few CCS projects that seek to exploit the benefits of CO₂ EOR will be viable if they are restricted to a single sink. This is because, for EOR, CO₂ demand will be determined by the characteristics of the reservoir and the operation of the facilities; and not, primarily, by a desire to sequester CO₂. However, CO₂ will be produced at a constant rate. This implies that for EOR, the infrastructure will need to link a number of potential EOR targets and represent a common "CO₂ pool". The infrastructure may need to be sufficiently flexible to divert CO₂ from the pool to pure storage when CO₂ demand for EOR is not matched to CO₂ supply.

Timeline for Deployment

In addition to the challenges familiar to all major engineering projects, the following additional factors impact on the programme for realising the maximum benefit from CCS projects linked to EOR schemes:

- First-in-class application of technology
- Considerable scope, especially of infrastructure
- Mix of greenfield and brownfield installation
- Mix of onshore and offshore operations
- Complexity of commercial structures
- Policy and regulatory issues
- Planning consents, especially onshore
- Availability of specialised resources (skills and plant/vessels, especially offshore if the oil price remains high)

It is therefore likely that the first phase of such a scheme would have a lead-time from initiation to start-up of approximately eight years. We would therefore anticipate that a project initiated in 2006 would start operations in 2014.

Subsequent phases would then increase the flow of CO₂ over a period of perhaps 6 years.

The Need for Public Sector and Private Sector Cooperation

The potential benefits of CCS are manifold:

- It could contribute to the UK realising the social, economic and environmental benefits of reduced emissions.
- It could contribute to the UK realising the economic benefits of developing world-class technology and operational experience; and
- It could contribute to the UK realising the economic and social benefits of increased recovery of indigenous hydrocarbon resources.



However, the challenges and costs are also manifold.

The benefits and costs cut across industrial sectors (power generation, engineering, infrastructure, oil and gas, manufacturing, legal, etc.) and across public sectors (spatial planning, tax, security of energy supply, emissions targets and obligations, etc.). This is especially true for the CO₂ infrastructure.

It will only be through public-private cooperation at all stages – not least the planning stage - that such an ambitious, but ultimately mutually beneficial, project can be achieved in a sustainable manner.

Q. How do the potential CO₂ savings compare with other options for reducing carbon emissions?

In terms of increasing net costs per ton of CO₂ abated, the main abatement options that Shell is considering are:

- CO₂ sequestration with EOR
- Efficiency improvements
- Heat and power cogeneration
- Wind farms
- Geological CO₂ sequestration

We would very much appreciate the opportunity to establish the CO₂ reductions these options could potentially deliver for the UK in discussion with the Government.

Shell has now invested over US \$1 billion in alternative energies, making it one of the world's leading companies in the sector. We are working in a number of areas that we believe will make a contribution to the UK's climate change programme and its CO₂ targets, such as the use of renewable energy and alternative fuels for transport including biofuels and hydrogen.

We believe that offshore wind is vitally important to delivering the UK renewables target and this in turn is a key component for delivery of its CO₂ target. Offshore wind could make a significant contribution to renewable electricity over the next 5 to 10 years and has an important part to play in helping the UK to move towards a low carbon future by bridging the electricity generation gap in the medium term until the longer-term technologies can be brought onstream.

Measures for tackling emissions from road transport need to be set within an overall framework of measures for all energy sources. According to the International Energy Agency's forecasts of future energy use, petrol and diesel are likely to provide the vast majority of transport fuels globally to 2030 and beyond. However, bio fuels are realistic contenders as major low carbon fuel sources for the future. Ethanol from food crops and bio-diesel from plant oils serve as an entry point but have limited potential for further cost reductions. They may also be limited by land-use considerations. New fuels based on a wide range of non-food biomass, including residues and energy crops, could overcome these limitations while further reducing CO₂ emissions.

Shell is involved in the development of advanced bio fuels that have the potential for larger greenhouse gas savings, lower costs for the consumer and opens up a range of new sources of biomass, including waste. This will ensure that bio fuels with a higher potential to reduce carbon emissions will be introduced into the market.

We are also actively supporting the early development of a long-term hydrogen infrastructure for fuel, progressing from hydrogen produced initially from hydrocarbons to ultimately hydrogen produced from renewable sources. Shell is the only major energy company involved in fuel cell vehicle demonstrations in all three major hydrogen markets – North America, Europe and Japan.

The next five to ten years will be important in defining the competitive landscape with the possibility of affordable private hydrogen based vehicles gradually coming into use, leading to mass production from 2013 onwards. Hydrogen buses (fuel cell or hydrogen combustion engine) will be introduced earlier than this in key urban centres. Growth of the hydrogen market will depend on funding the transition to mass production.

Car manufacturers, energy companies and governments will need to work together to deliver a well co-ordinated rollout of the necessary infrastructure. Production must be economic and there needs to be a steady migration pathway to CO₂-free hydrogen.



2. TECHNOLOGY

Q. What are the different technological options currently available and in development for each stage of the CCS process – and what are the costs of these options?

Please refer to Table 1 below.

Q. What scope is there for applying these technological options to different forms of power generation (particularly gas and coal) and other large-scale sources of CO₂ emissions, and can they be installed on the basis of both new-build and retrofitting?

Table TS.3 on page 25 of IPCC Technical Summary Ref [2] gives a summary of CO₂ capture costs for new power plants based on current technology. Please also refer to Table 1 below.

Q. At what level of market readiness are these various technological options?

The market readiness of various technology options is provided on page 18 of the IPCC Technical Summary in Table TS.1 Ref [2], summarised and augmented in Table 1 below.



Table 1: Summary of technology options along the CCS value chain

Technology Option	Costs	Scope application with different fuels	Scope for application with other large scale emitters	Suitability for use in new-build or retro-fit	Market readiness	Limitations within CCS value chains
CAPTURE						
Pre-combustion						
Syngas production from NG with CO ₂ /H ₂ separation	Refer to response on "Cost"	Gas	Refining Fuel for vehicles	New	Now (higher cost) 2015 (lower cost)	
Oxyfuels	Refer to response on "Cost"	Gas Coal	Refining Process heat	New	2012 (coal high-cost) 2015 (gas low-cost)	
Coal gasification	Refer to response on "Cost"	Coal Pet coke	Refining Fuel for vehicles	New	Now (higher cost) 2012 (lower cost)	
Post-combustion						
Coal	Refer to response on "Cost"	Coal		New	2010 (higher cost)	Contamination of storage
Gas	Refer to response on "Cost"	Gas	Refining	New Retro	Now (higher cost) 2012 (lower cost)	
TRANSPORTATION						
Pipeline (Carbon Steel)	Refer to response on "Cost"	All	All pure, dehydrated CO ₂ sources	New / Re-use	Now	Economically viable up to approximately 1,000 km in length
Pipeline (Corrosion resistant alloy)	Refer to response on "Cost"	All	All pure CO ₂ sources	New / Re-use (limited availability)	Now	Economically viable up to approximately 1,000 km in length
Ship	Refer to response on	All	All pure CO ₂ sources, following	New / Conversion?	Now	Economically viable above approximately



	"Cost"			cryogenic liquefaction			1,000 km shipping distance
STORAGE							
Saline Aquifer	Refer to response on "Cost"	All	All	All	N/A	Now	
EOR	Refer to response on "Cost"	All	All	All	Use of existing wells may be possible with recompletion	Now	
Oil/Gas Field Storage	Refer to response on "Cost"	All	All	All	Use of existing wells may be possible with recompletion	Now	
Mineralisation	Refer to response on "Cost"	All	All	All	New	2020?	



Q. What limitations exist when it comes to selecting from the options at each stage to form a full CCS process?

Technologies for the capture of CO₂ are relatively well understood today based on industrial experience in a variety of applications. Similarly there are no major technical or knowledge barriers to the adoption of pipeline transport or to the adoption of geological storage of captured CO₂. However the integration of capture, transport and storage in full scale projects is needed to gain the knowledge and experience required for a more widespread deployment of CCS technologies. Section 10 on page 45 of IPCC Technical Summary Ref [2] identifies the current gaps in knowledge that are important to facilitate the decision making process about the large-scale deployment of CCS.

Technology General

We view CCS as one of a suite of technology measures available to assist us in reducing greenhouse gas (GHG) emissions and therefore play our role in mitigating the potentially dangerous impacts of climate change. We support and are involved in the development and deployment of the technology as a safe, reliable and ultimately cost-effective mechanism to reduce industrial CO₂ emissions. It is our view that:

- The technology required for geological sequestration is proven and in common use in the oil and gas industry for enhanced oil recovery. This fits with our business and builds on our strength in understanding subsurface structures and processes;
- Wide-spread, large storage capacity has been identified that is sufficient to store significant amounts of global CO₂ emissions over the next century;
- Research has shown that CO₂ can be securely stored for thousands of years or longer, with ongoing work and field trials to further clarify the risks involved;
- Storage site leakage is not an inherent design feature of all CCS projects, but rather a function of site selection, operational management and closure of the site. An approvals mechanism for CCS projects must incorporate the necessary assurances over site selection, permanence, monitoring, remediation and allocation of liability for any third party damage and remediation in the event of seepage emissions.

These views are supported by the IPCC, when it concludes that:

“With appropriate site selection based on available subsurface information, a monitoring programme to detect problems, a regulatory system and the appropriate use of remediation methods to stop or control CO₂ releases if they arise, the local health, safety and environment risks of geological storage would be comparable to the risks of current activities such as natural gas storage, enhanced oil recovery (EOR) and deep underground disposal of acid gas. Observations of engineered and natural analogues as well as models suggest that the fraction [of stored CO₂] retained in appropriately selected and managed geological reservoirs is very likely to exceed 99% over 100 years and is also likely to exceed 99% over 1000 years”.

Mineral Carbonation

One of the options for CO₂ storage is mineral carbonation, which involves converting CO₂ to solid inorganic carbonates using chemical reactions. We are studying the feasibility of mineral carbonation but there are a number of issues that still need to be clarified and the extent to which mineral carbonation may be used cannot be determined at this time.

Coal

Globally carbon capture and storage is going to have to be associated with the use of coal, and possibly also gas, in power generation if climate change is going to be effectively tackled. This is also likely to be true if the UK is to meet its carbon reduction targets.

Coal gasification for combined cycle power generation, commonly known as IGCC, is a leading technology that is especially applicable for carbon capture and storage as it allows for a cost and process efficient separation of CO₂. In an IGCC the CO₂ is separated from the process stream prior to combustion. At this point the process stream is smaller and at high pressure, both enabling a more cost-efficient separation.



3. ENGINEERING AND MANUFACTURING CAPABILITY

Q. Are there skills gaps that could create barriers to the development of CCS in the UK?

A growing skills shortage could lead to increased costs for companies and delays in projects.

As the current supply of skilled individuals reduces there is increasing demand for those that remain. This war for talent is increasingly occurring in a global context where workers are also looking for opportunities in other countries, within other industries.

There are simply not enough young people in the “pipeline”, with many university science and engineering departments showing a low uptake of the degrees which are relevant eg chemical and process engineering along with geology. There have recently been several high profile closures of UK university science and chemistry departments.

The current North Sea skills shortage is one of the most fundamental challenges that could prevent the industry from maximising the potential of the Continental Shelf and other opportunities presented by CCS technologies. This is not an individual company issue, nor is it an industry issue or even a Government issue. There are many different organisations and agencies which need to play a part in its resolution eg Cogent, UKOOA, which has been looking at skills shortages for the offshore oil and gas industry for some time, and the ECITB (Engineering Construction Industry Training Board).

4. REGULATION, LIABILITY AND PUBLIC ACCEPTANCE

Q. What scope is there to develop and use CCS within the current regulatory framework?

None of the existing regulatory or legislative frameworks were developed with CCS in mind and they do not address the long-term liability issue. There are no regulatory precedents for the injection of large amounts of fluids into the underground for the purpose that they remain there for long periods of time.

Q. What regulatory framework would need to be put in place to support the development of CCS technology while also ensuring protection of human health and the environment?

The EU needs to address the legal uncertainty about the implications of the OSPAR Convention (for the permissibility of CO₂ storage under the North Sea) and the London Convention and Protocol. Existing legal frameworks still do not reflect the technological advances, nor recognise the environmental drivers in storing CO₂ – the balance between storage risks and reducing atmospheric CO₂ levels. However, the existing framework can be used for the operational aspects of CCS as this already has some elements in it that addresses issues such as safety, respect for human health and the environment.

It is important that the UK Government continues to show leadership on CCS by accelerating actions both domestically and on the EU level towards removing the regulatory and legal disincentives for CCS.

Q. What additional costs and considerations are created by the long-term liability implications attached to CCS, and how can these be best managed?

The key barrier is the issue of liabilities. Whilst Governments in some countries are assuming the waste liabilities of their nuclear businesses, at present companies are required to assume CO₂ liabilities in perpetuity. We do not know what the costs are likely to be but the issue of long-term liability will need to be resolved before the UK will be able to scale up CCS. It would be commercially unworkable for companies to take on unquantifiable liabilities when undertaking CCS projects.

Ultimately the Government will have to take on the long-term liability. A process is needed that regulates how that liability is transferred from the operator to the Government and the Government will need to inform industry what its expectations are on this aspect. Transfer could be at the point where it has been established that the CO₂ is stable. Stable means until trapping has proved that everything is working as expected. There are cost implications for the transfer – the operator would cover the costs until the point of transfer, at which time the Government would then have to take on the costs. Industry will need protocols in place to ensure the transfer of liabilities from the operator to the Government so that it knows what legal implications it might face.

Q. What issues arise concerning (short-term) liability for CO₂ at particular points in the CCS process? Are there costs attached to these and what are they?

The key technologies required to capture carbon dioxide from fuel or flue gases are well established in power generation or other process facilities and Shell is a leading provider of many of these. The



technology required for geological sequestration is proven and in common use in the oil and gas industry so short-term liability does not raise any novel issues as these are standard. We already know how to operate and how to handle CO₂ using our expertise from the oil and gas industry.

Q. What might be the likely public reaction to concerns about CCS, and how could concerns be addressed?

Public acceptance of CCS in the UK has not been established and is an important area that needs to be addressed. Governments and other stakeholders should put some focus on educating the public to help them understand the costs and benefits of CCS.

5. COST

In answer to the various questions on costs the best available analysis can be found in Table TS.10 on page 40 of the IPCC Technical Summary Ref [2], which gives a range of total costs for CO₂ capture, transport and geological storage based on current technology for new power plants using bituminous coal or natural gas.

We would also draw your attention to page 9 of the IPCC Summary for Policymakers Ref [3] “What are the costs for CCS and what is the technical and economic potential?” and chapter 8 on page 38 of the Technical Summary, Ref [2], “Costs and economic potential”.

Q. How does EOR using CO₂ compare in cost terms to EOR using other means?

Most EOR schemes rely on a complex value chain, which is heavily influenced by many factors. The major cost for most EOR schemes is the cost of the injectant (CO₂, N₂, hydrocarbon gas, polymer, surfactant, steam, etc.).

- Hydrocarbon gas is highly attractive where stranded (e.g. Alaska), but highly unattractive where there is easy access to markets (UKCS). Hydrocarbon gas injection has only been attractive in the North Sea where capacity or tariff constraints restricted gas sales (e.g. Magnus, Snorre).
- N₂ gas could be extracted from air. However, there are cases where N₂ has to be extracted from gas to meet sales specifications, so in this case N₂ would be available at lower cost.
- Costs of polymers and surfactants are linked to oil price (feedstock) and have not been shown to be economic on a large scale, especially with the large well spacings offshore.
- The major cost for CO₂, apart from the CO₂ itself, is corrosion resistant materials, especially where these have to be retro-fitted.

Q. Is the use of CO₂ for EOR appropriate on the UK continental shelf and at what stage in the life of a specific field is it appropriate to use EOR?

Use of CO₂ is appropriate for many UKCS fields - light oils, large well spacing, relatively deep reservoirs to assure miscibility. However, specific field characteristics (heterogeneity, permeability, dip, reservoir thickness, oil properties, presence of a gas cap, etc.) will influence how appropriate it is in a particular case.

Ideal timing is dependent upon a combination of factors:

- The need for production data to understand the reservoir before committing to EOR, which is an order of magnitude more complicated than primary/secondary recovery.
- The need to plan for EOR to start before the field becomes uneconomic.
- The preference to operate EOR above the minimum miscibility pressure, which may be an issue with fields produced under depletion.
- Any link to life of field facilities or export infrastructure.
- Ideally the possibility of late life EOR should be recognised during initial design - flexibility, materials etc.
- In most cases it would be appropriate to start a CO₂ EOR project when around 80-90% of the primary/secondary ultimate recovery has been produced, but each specific case should really be evaluated on its own merits.



6. WIDER POLICY FRAMEWORK AND OTHER ISSUES

Q. What is the impact of the current policy framework on the development of CCS? and

Q. Are there any particular issues that need to be taken into account with regard to CCS when considering the use of policy mechanisms to reduce CO2 emissions in the UK economy?

Shell supports a policy framework that encourages a transition to a low carbon energy future through a diverse portfolio of primary energy solutions. These include “greener fossil fuels” using clean technology and the use of indigenous renewable resources, particularly offshore wind. Clean coal technology is also going to be vital in the energy mix. The focus that the Government is giving on these issues is encouraging.

CCS projects are long-term in nature, requiring high up front investments and potentially long periods of operation (10 to 50 years). There is a need to establish a set of regulatory and fiscal conditions that manage some of the risks and remove uncertainty that is a barrier to investment. We would welcome further discussion on appropriate stable, predictable and long-term incentive structures. Without a clear and comprehensive effective support mechanism the trickle of investment will not close the CO2 gap.

Most importantly, we believe that any support mechanism for CCS should be related to the quantity of CO2 emissions abated.

The Renewables Obligation (RO) should not be extended to encompass support for CCS technologies. Doing so would make the RO more difficult to understand, more opaque and would not guarantee delivery. Easy fixes around widening the definition or eligibility of certain sources will not deliver lasting projects and will at the same time severely jeopardise investor confidence in renewables, with potentially dire consequences for renewables implementation in the UK. We believe that offshore wind can provide the scale that will be essential to reaching Government targets for renewable energy, which are a key component for achieving the CO2 targets. To ensure that new and emerging technologies like CCS and offshore wind reach commercialisation, they need to be supported to the point that they can compete on an equal footing with the established technologies.

ETS and CDM

We are supportive of, and active in the development of all emissions trading mechanisms (the EU ETS, the Clean Development Mechanism and Joint Implementation) and believe that both the ETS and CDM provide incentives for the deployment of clean technologies such as CCS.

Whilst the EU ETS is the most promising mechanism for incentivising CCS, the current price of CO2 is not sufficient and industry will need much greater confidence in future carbon prices to justify investment in CCS given the long depreciation times (30 years or so) of these projects. The EU ETS in its present form provides insufficient signals for long-term investments. Including CCS within the EU ETS via the reporting and monitoring guidelines is important, but a discussion is also needed on the future structure of the ETS (eg longer allocation periods etc) so that it can stimulate investment in CCS and other abatement technologies.

We are attaching two letters [\[4\]](#) [\[5\]](#) on these issues, which spell out our views on the details relating to the inclusion of CCS into the Kyoto trading mechanisms.

Planning

We described above in our section headed “Potential Carbon Reductions” the importance of infrastructure to the large scale deployment of CCS and the need for co-ordination and co-operation. The planning regime in the UK impacts the investment framework for almost all parts of the energy supply chain, including new power stations, wind energy, gas storage and grid upgrades. This also applies to the CCS value chain and CO2 transport infrastructure. International standards will be required for coal fired power plants to ensure that there is a level playing field. In some cases old fashioned coal fired power plants are allowed to be built in some parts of Europe while other parts of Europe have a far more stringent application of permitting procedures.

Research and Development

There is extensive existing support for research and development activities but technology deployment and infrastructure development need further consideration.



Appendix

Shell is working with national geological services, research institutions and other energy companies to develop the science and methodology that is required to comprehensively assess the environmental performance of geological sequestration. For example:

- In the United States, the West Coast Regional Carbon Sequestration Partnership and the CO₂ Capture Project, which is a joint industry project comprising eight of the world's leading energy companies. Technologies developed by this project will be used in many different industries and applications around the world.
- The Australian based CO₂CRC programme where Shell is an industry sponsor. This is a research consortium that is looking into both CO₂ capture technologies and geosequestration. The CRC intends to launch a pilot CO₂ sequestration project in the State of Victoria within the next year.
- Conducting, with the support of the European Commission and in association with Geo-Research Center, Potsdam and other partners, a CO₂ sequestration field test near Berlin that aims to provide detailed insight into the subsurface behaviour and movement of CO₂.
- Studying novel ways to manage natural subsurface chemical reactions with a view to further increase the safety and security of CO₂ storage.

We are developing both pre- and post-combustion capture technologies. Pre-combustion technologies include gasification and amine, and post-combustion technologies are being considered for a North Sea field and a Gas-to-Liquids project in the Middle East.

Clean Coal

Shell has almost 30 years of experience in developing and using coal gasification. The Shell coal gasification process is clean, none of the constituents in the coal are wasted and it is flexible as it can operate on a wide range of coal qualities. It boasts extremely low SO₂, NO_x, particulates and heavy metal emissions. The Shell technology was put into commercial operation in 1994 in The Netherlands and today this plant remains one of the most efficient and cleanest large scale IGCC plants in the world.

Enhanced Oil Recovery

Shell has recently announced a joint venture with Statoil to develop the world's largest project using CO₂ for enhanced oil recovery offshore. The project consists of a new gas-fired power plant and methanol production facility at Tjeldbergodden to provide electricity in mid-Norway and capturing the CO₂ and utilising it to enhance oil recovery at the existing Draugen and Heidrun offshore oil and gas fields. Power from the plant will also be provided to the offshore fields, enabling near zero CO₂ and nitrogen oxide (NO_x) emissions from these installations. The various elements of the project will be phased in during the period 2010-2012. Establishing the CO₂ value chain for this project will be technologically and commercially challenging.

Research and Development

Shell initiated a study with Imperial College on the combined H₂/CO₂ infrastructure for Greater London transportation systems, which is looking at the question of whether large scale, central production is preferred to capture CO₂ or small-scale decentralised production that fits better H₂ needs. Similar considerations need to be investigated for centralised or decentralised heat/power generation. This research began in November 2005 and is looking at how and where to produce hydrogen from a fossil fuel feedstock, in association with carbon capture and storage, giving full account of the transportation and distribution issues of both hydrogen and carbon dioxide. The project is being co-ordinated by Professor Nigel Brandon, Shell Professor of Sustainable Development in Energy at Imperial College. One PhD student and two Post-doctoral research associates are working on the project. This is a considerable piece of work that will take three years and has been specially selected to address an area that is of specific interest to Shell. We anticipate that the project, if successful, will be continued and may serve as a platform for further study.



References and Attachments

- [1] World Business Council for Sustainable Development's "Pathways to 2050: Energy and Climate Change"
- [2] UNEP/WNO IPCC Special Report: Carbon Dioxide Capture and Storage – Technical Summary
- [3] UNEP/WNO IPCC Special Report: Carbon Dioxide Capture and Storage - Summary For Policy Makers
- [4] Letter to the EU Commission regarding CCS in the EU ETS
- [5] Letter to UNFCCC regarding CCS in the CDM