



Scottish Power

**Carbon capture & storage:
Barriers to commercial deployment**

**HM Treasury
Consultation response**

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ScottishPower consultation response

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EXECUTIVE SUMMARY

SCOTTISHPOWER RESPONSE TO 'CARBON CAPTURE AND STORAGE: BARRIERS TO COMMERCIAL DEPLOYMENT'

ScottishPower welcomes the opportunity to contribute to the HM Treasury consultation on the barriers to the development of carbon capture and storage capabilities in the UK.

The UK faces a considerable challenge in the power generation sector, with a need for significant investment in new generation plant over the coming 15 years. This investment should not only deliver an energy system where diversity ensures security of supply, but also one which enables us to meet our national carbon reduction targets. Security of supply and reducing emissions are thus closely linked, and we believe that clean coal technologies incorporating carbon capture and storage (CCS) have the potential to meet these twin needs as part of a broad range of solutions including renewables, new CCGT technology and demand side initiatives.

Existing coal plant is an important bridge between today's generation mix and tomorrow's, which ideally will include a significant contribution from clean coal and CO₂ sequestration technologies. Further, it helps support our indigenous coal supply industry. Beyond 2015, the UK needs to develop real options for new low carbon technologies. Clean coal, CO₂ capture and geological sequestration have a potentially significant role to play in the UK energy mix and an indispensable role to play at a global level. If properly managed, they can be introduced to complement the extension of conventional coal resources in a manner that is both economically efficient and maximises the contribution of coal resources to energy security.

It is possible to envisage a 3-stage policy timetable that supports (1) the use of conventional opted-in, environmentally compliant coal plant up to 2015; (2) between now and 2015 new coal plant using capture ready technology, as well as commencement of pilot CCS demonstration projects; and (3) the introduction of commercially feasible clean coal plant with full capability for capture, transportation and storage of CO₂ some time between 2015 and 2020. Whilst there are technical, legal and environmental unknowns, we believe these challenges can be overcome. CCS will however require development funding and capital grant support if it is to be economically viable in the next 10-15 years.

Power equipment manufacturers and the power generators are well positioned to support the development of capture ready power generation technology and Government should initially focus on the establishment of a clear regulatory and fiscal framework to justify CCS investment. Before there will be large-scale UK investment in CCS, there will need to be:

- Government leadership to set out national policy on CCS, co-ordinate and stimulate infrastructure investment, and to help license new technology and storage sites.
- Development of the regulatory framework to offer a clear licensing and legal framework, substantial and sustained financial support mechanisms, a willingness to expedite planning of new plant and infrastructure and an early development of environmental standards.
- Clarity on future EU ETS policy beyond Phase II to help energy companies develop options for long-term energy plant investment.

Currently some small-scale projects are coming to fruition with unique engineering solutions, but no consistent framework has yet been developed. ScottishPower is supportive of the development of CCS technology capability in the United Kingdom and we would be willing to participate in a pilot demonstration project.

RESPONSE TO CONSULTATION QUESTIONS

1. Barriers to the commercial deployment of CCS in the UK

Question: What are the barriers to the commercial development of CCS?

Whilst it is clear that there remain technical unknowns in the development of CCS which will require significant development investment to allow the technology to become competitive in the next 10-15 years, the real barriers to CCS development relate to the absence of an appropriate legislative and regulatory framework which CCS will operate under, a lack of clarity around how CCS will be accommodated within the current industry structure and the relative uncertainties surrounding CCS compared to other generation technologies. In addition, the economic uncertainties around the future value of CO₂ make investment in this area challenging.

With the appropriate legislative, regulatory and fiscal policy structure it is likely that barriers to CCS development will be overcome in the medium term and it can develop as an important element of the UK plant portfolio longer term, and act as a viable alternative to a large scale new nuclear power build programme.

(a) Developing the legislative and regulatory framework

To allow the development of CCS it will be necessary to provide greater clarity of UK energy policy over the long term. In the ScottishPower response to the Energy Review consultation we outline a potential timeline for development of CCS between now and 2020:

Now – 2010: Make progress on R&D for CCS technologies

2010 – 2015: Develop future options for new low carbon baseload plant and CCS

2015 – 2020: Construct new low carbon baseload plant and CCS

A key barrier to CCS development at present is the absence of an established legal and regulatory framework under which power generators and developers of carbon capture, transportation and storage facilities will be expected to operate. A national policy will be an essential first step to provide clarity and stimulate the necessary infrastructure investment.

Areas to be addressed as highest priority as we move forward will include the following:

- Amendment to international and European environmental legislation applicable to power generation to govern the environmental standards under which plants will operate, technological methods of CO₂ capture at source and the compliance regime for recording of CO₂ capture;
- Establishment of the regulatory structure for the transportation of CO₂, including determining responsibility for the development of a national land or sea-based infrastructure or pipeline system to carry CO₂ from production centres to storage areas, agreement of third party access rights and agreeing the regulatory structure for remuneration of CO₂ transportation;
- Development of an appropriate licensing framework for the storage of CO₂, including where appropriate, amendment to OSPAR convention, ensuring CCS projects are legally permissible, determining the ultimate legal ownership of storage facilities such as underground aquifers, addressing legislation on the prohibition of dumping wastes at sea, developing health and safety legislation for CO₂ storage, monitoring and verifying CO₂ storage and determining long term responsibility for CO₂ liability once stored;

- Demonstration of a willingness to fast track planning of new plant and associated infrastructure.

The UK Government has a critical role to play in more accurately charting the nation's CO₂ storage inventory potential, as there remains uncertainty around the scale and location of storage potential in the North Sea and UK Continental Shelf (UKCS). We believe the Government could usefully commission work (or put in place a framework to have this work completed) within a relatively short timescale, to enable the producers of CO₂ to better understand where the opportunities for storage exist.

In terms of industry structure, it is clear that a whole host of new commercial relationships will need to be formed. Development of CCS will require the involvement of a large number of business sectors including producers of power generation technology, fossil fuel suppliers, the power generators, electricity and gas shippers, operators of storage facilities and offshore oil and gas suppliers. It will be important therefore to develop the regulatory and legislative framework for CCS in a manner which facilitates a collaborative approach across the entire CCS chain.

(b) Economic barriers to CCS development

The two primary economic barriers to CCS development at present are the lack of long-term visibility around the cost and value of carbon and the relative cost competitiveness of developing CCS relative to other established generation technologies.

Long-term value of carbon:

The establishment of a stable regulatory regime – in which the value of CO₂, and specifically CCS to the producer, is likely to be stable over a sufficiently long timescale is essential to stimulate the required investment in CCS technology. Clarity of future policy with respect to EU Emissions Trading Scheme is therefore clearly vital.

We fully support the EU Emissions Trading Scheme (ETS) as the overarching framework for control of CO₂ emissions across the EU. In particular:

- Phase II of the EU Emissions Trading Scheme should be implemented in a way that delivers short- to mid-term supply security by allowing cleaned-up coal (Flue Gas Desulphurisation (FGD)) plant to contribute fully and to act as the bridge to even cleaner Carbon Capture and Sequestration technologies.
- There should be strong support for Phase III ETS, and a sustained push to clarify the post 2012 rules at a European level. This will set the investment framework needed for larger baseload generation in the mid-long term.

Recognising the potential difficulty in being able to arrive at a decision on ETS Phase III methodology and permit allocation at this point, the UK Government should reinforce their commitment to carbon reduction policy goals by, as a minimum, setting and communicating the CO₂ reduction targets they will aim for over the medium and long term.

In the absence of greater clarity about the long-term value of carbon, the risk profile of CCS investment is likely to be prohibitive and will undoubtedly act as a barrier to investment.

Cost competitiveness of CCS:

At present, Carbon Abatement Technologies (CAT) such as CCS cannot compete on an economic basis with conventional power generation from coal and Combined Cycle Gas Turbine (CCGT) plant. Indeed, given the additional costs expected to be incurred at each stage of the carbon capture, transport and storage chain, it is unlikely to be fully economic

in the absence of a world in which there is a high cost associated with the emission of CO₂.

In terms of CO₂ abatement, from a pure cost standpoint and under certain scenarios, the full CCS cost can be considered competitive with renewable generation such as onshore wind, offshore wind, biomass energy crops and marine energy.

Despite the relative comparability of cost with other low carbon technologies, it is unlikely that CCS projects will develop to commercial scale without the aforementioned clarity on the long term price of carbon and an appropriate use of direct or indirect fiscal mechanisms such as capital grants or tax incentives to stimulate investment.

ScottishPower is supportive of the development of CCS technology capability in the United Kingdom and, assuming the regulatory and market frameworks can be put in place, we would be willing to participate in a pilot demonstration project.

2. Potential carbon reductions

Question: 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? How do the potential CO₂ savings compare with other options for reducing carbon emissions?

To achieve the maximum reduction in CO₂, a solution focused on coal fired power generation will be required, as coal emits more than twice the CO₂ / MWh compared to CCGT power generation. It is sensible therefore that commercial scale trials on the applicability of CCS in the United Kingdom focus on carbon capture from existing coal fired power generation.

Developments in Clean Coal Technology (CCT) come in various forms and the reduction in CO₂ varies greatly depending on the technology applied:

- **Fuel switching to lower carbon alternatives**

Example: biomass co-firing
Potential CO₂ saving: 5 – 10% (Note: by 2015 8GW of opted out coal plant will close and be unavailable for co-firing)

- **CO₂ reduction from high efficiency conversion processes**

Example: Pulverised Coal Combustion (PCC), Fluidised Bed Combustion (FBC), Integrated Gasification Combined Cycle (IGCC) technologies
Potential CO₂ saving: 10 – 30%, most in the 20 – 25% range

- **Virtual elimination of CO₂**

Example: Carbon Capture & Storage
Potential CO₂ saving: 80 – 90%

Whilst currently available coal conversion techniques can deliver up to 30% reduction in carbon emissions, the development of near “Zero” Emission Technologies (ZET) such as CCS clearly provide the maximum potential reduction in CO₂.

To illustrate the saving potential, assuming a 1,000MW conventional coal fired generation station, operating at a 70% load factor with CCS technology fitted and delivering a 80% reduction in CO₂ would equate to an annual saving in CO₂ of around 4.7 million tonnes. By

way of comparison, the development of an equivalent capacity onshore windfarm, operating at a 30% load factor and delivering a 100% reduction in CO₂ would equate to an annual saving in CO₂ of 2.5 million tonnes.

3. Technology

Question: What are the different technological options currently available and in development for each stage of the CCS process – and what are costs of these options? 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? At what level of market readiness are these various technological options? What limitations exist when it comes to selecting from the options at each stage to form a full CCS process?

Generation

The existing fleet of power generating stations in the UK are generally from the most commonly available conventional PCC technology. Supercritical PCCs are based on conventional power plant technologies but operate at higher (supercritical) pressures and temperatures in order to increase plant efficiency.

Currently the most widely used clean coal technology is FBC but has generally suffered from a lack of economies of scale to compete with PCC plants fitted with FGD. The most advanced low carbon technology currently is IGCC, with demonstration projects in operation since the mid 1990's, although few, if any, have successfully included the full integration of carbon capture.

As stated previously, the conventional technologies listed above could be implemented as a means of CO₂ *reduction*. To achieve CO₂ *elimination*, CCS technologies would almost certainly require to be retrofitted or designed into one of these existing conventional technologies or, perhaps more likely, developed from scratch on site.

A key consideration in the development of CCS technology is the resulting energy losses arising from the energy used in the CO₂ capture process (currently 6 – 12 percentage point reduction to station efficiency), and assumptions around future carbon price and volatility are critical factors in assessing the economic viability of CCS technology.

From a technological standpoint there are three primary options for CO₂ *capture*:

- **post combustion CO₂ capture** – chemical absorption, flue gases scrubbed using an amine solution, amine heated to release high purity CO₂. Requires large and expensive equipment.
- **oxyfuel combustion** – oxygen separated from air prior to combustion with some CO₂ rich flue gas recycled to the combustor. Separation process expensive in terms of capital and energy costs.
- **pre combustion CO₂ capture** – involves reacting fuel with oxygen and or steam in an IGCC gasifier to give carbon monoxide, which is then reacted with steam to give CO₂ and hydrogen. Hydrogen is then burned within the IGCC process.

From an economic standpoint, the pre combustion option is likely to be the most cost effective method of capture over the longer term, due to the resultant high CO₂ concentration of the flue gases reducing the need for treatment prior to storage.

Long term storage below surface

Once captured there are four main options, which could be considered feasible for the *storage* of CO₂, involving pipelines from power station to:

- **depleted oil or gas reserves** – oil and gas reserves consist of porous rocks covered by impermeable cap rock (often dome shaped), making them suitable for CO₂ storage. This reduces exploration and capital costs by re-using infrastructure to transport and inject CO₂. Injected CO₂ can also be used as a means of Enhanced Oil Recovery (EOR);
- **unminable coal beds** – injection of CO₂ into suitable coal beds where it will be absorbed onto the coal, locking it in permanently (assuming the coal is never mined). The CO₂ displaces methane which exists in the coal and can then be used for power generation;
- **deep saline reservoirs / aquifers** – use of underground water filled strata (aquifers) to store CO₂. The CO₂ partially dissolves in the water in the aquifer and in some cases reacts with minerals to form carbonates, permanently locking it in the ground;
- **deep ocean** – the ocean contains 50 times more CO₂ than the atmosphere and has the capacity to retain more CO₂ than it releases over time. The retention time depends on the depth at which CO₂ is injected.

Two of the options currently considered as offering potential economic benefit are enhanced oil recovery from depleted oil reserves and enhanced methane production from unminable coal beds. Both these options realise fuel sources which would otherwise be unavailable.

In addition, through its North Sea oil and gas assets and access to large-scale underground aquifers, the UK has an advantage over other European countries in terms of access to potential sites for carbon storage.

The applicability of the alternative capture and storage techniques to existing power generation technologies is however, as yet, largely untested. Clean coal technology for carbon reduction such as IGCC plants have been in development since the late 1980's but have largely been developed as new build demonstration plants rather than retrofitting existing coal plants.

In terms of post combustion CO₂ capture, CO₂ represents only a small proportion (9-14%) of the flue gas emitted by a power station and the low CO₂ concentration requires that a large volume of gas has to be handled. Resulting in large equipment which is expensive to build and operate, this is likely to render the technology unsuitable for the retrofit of an existing coal or CCGT station.

Although pre combustion capture would involve a more radical change to the power station design, most of the technology is already well proven in ammonia production and other industrial processes. It is also expected that it will be possible to burn hydrogen in an existing gas turbine with little modification but this is not yet commercially proven technology.

Overall, there are likely to be a number of engineering and logistical challenges in attempting to retrofit existing power generation to accommodate CCS technology. Whilst certain components of the existing station (land, electrical connections, services, office buildings) would be unaffected by the retrofit, the majority of station equipment (transformers, generator, condenser, combustion plant, turbines) would need to be completely replaced or their design significantly amended to accommodate CO₂ capture. The fitting of substantial new equipment to old generation plant, particularly to utility boilers and furnace equipment, is generally considered to be ineffective and ultimately impractical.

There are likely to be relatively few instances in the UK where retrofitting an existing coal fired or CCGT generation station for CCS will be practical. The sites of existing coal or

CCGT plant may hold certain cost advantages from the ability to use the current site and associated infrastructure, provided the physical location of the site is such that it supports ease of CO₂ transportation and storage. Practical examples of such sites could potentially include those coal-fired plants which have been opted out of the EU Large Combustion Plant Directive. Current locational transmission charging regimes are likely to act as a barrier to the development of CCS in Scotland.

4. Engineering and manufacturing capability

Question: What would be the costs and benefits of early adoption of this technology in the UK? Are there skills gaps that could create barriers to the development of CCS in the UK?

As stated previously, the future development of CCS is dependent on the ability to overcome numerous technical and environmental uncertainties. The sub components of CCS (capture, transport and storage) are already the subject of several initiatives across the EU and internationally and as a result a key objective of Government policy should be the avoidance of duplication of effort and cost.

The UK has a number of natural advantages which put it in a strong position to lead in the development of CCS technology and to gain commercial and social benefits from its deployment, including:

- UK Government commitment to CO₂ abatement should encourage an early domestic market for CCS;
- The need to refurbish or replace a large part of the UK's coal and nuclear power generation capacity;
- Ideal geological formations for long-term storage of CO₂;
- Strong capabilities in offshore engineering oil and gas extraction and geological sciences.

Given the North Sea oil and gas assets and access to large-scale underground aquifers the UK has a natural advantage over other European countries in terms of access to potential sites for carbon storage. We therefore believe it would be sensible for the UK Government to focus its national emphasis on committing R&D expenditure to the development of specific prototypes for CO₂ transportation and storage, while playing a support role in international efforts towards developing and commercialising capture technology.

Any potential technological advantage from the early adoption of CCS in the UK is likely to accrue to the international engineering or power equipment manufacturers, perhaps in conjunction with oil and gas majors. It is recognised that a strong opportunity for innovation exists and the lead being shown by the UK in CO₂ abatement should be used to establish market opportunities for the deployment of CCS and other carbon abatement technologies.

From the standpoint of individual power generators, it is unlikely that there will be clear benefits from the early adoption of CCS technology. Indeed, given the current lack of a policy framework and clarity around the value of carbon, there are likely to be economic disadvantages and a high risk of shareholder value destruction from committing significant resources to CCS projects.

Under these circumstances, early adoption of transportation and storage technology would be best facilitated by Government support for a 1–2 year study to improve understanding of the economic and technical applicability of the various carbon storage options. Thereafter, establishment of an appropriately structured industry committee to commence work on drafting the appropriate regulatory and licensing arrangements for CCS and the

announcement of explicit fiscal support measures to encourage commercial trials of carbon storage will be required.

There are no specific skills gaps acting as a barrier to the development of CCS. Indeed, it is likely that there is significant technical expertise in the offshore oil and gas industry, which should be transferable to the new CCS technology. In addition, the work of the power engineering companies in the development of carbon reduction technologies such as IGCC will be invaluable in the advancement of CCS technology in the UK. The UK Government will have a clear role to play in pulling together the different pockets of expertise in a focused and coordinated way

5. Regulation, liability and public acceptance

Question: What scope is there to develop and use CCS within the current regulatory framework? 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? What additional costs and considerations are created by the long-term liability implications attached to CCS, and how can they be best managed? 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? What might be the likely public reaction to concerns about CCS, and how could concerns be addressed?

The current UK regulatory framework is not sufficient at present to facilitate the development of CCS technologies. Indeed, the fundamental end-to-end framework under which CCS projects could realistically be brought to commercial operation does not exist at present and will need to be developed with the relevant bodies.

The development of a policy framework to govern CCS projects will require changes to national and international legislative frameworks, environmental standards, regulatory policy and health and safety regulations. The framework will need to provide clarity on issues such as the following:

International:

- Recognise the OSPAR guidelines and framework for risk management of CO₂ storage;
- Assess the practical implications of transporting CO₂ across international boundaries;
- Secure international agreement that carbon storage is legal.

European:

- Determine the implication of CO₂ capture (reduction) for the operation of EU ETS, including calculation of emissions.

UK Government & Regulatory:

- Agree appropriate health & safety standards for the operation of CCS facilities;
- Develop environmental standards under which operators of CCS facilities will be expected to operate;
- Define the principles for the measurement and verification of CO₂ capture;
- Agree the regulatory structure for the operation and remuneration of CO₂ transportation activities;
- Commission work to chart the nation's CO₂ storage inventory potential;
- Establish the approach to monitoring, audit and verification of CO₂ storage;
- Outline the process for dealing with CO₂ leakage at storage facilities and the corresponding impact on marine environment and the atmosphere;

- Determine the appropriateness of the use of North Sea and UK onshore saline aquifers for CO₂ storage;
- Agreement on responsibility for the cost and environmental obligations resulting from long-term CO₂ storage liabilities;
- Put in place a planning and licensing structure to allow the fast track planning of applications for the development of CCS facilities.

In terms of the long-term liabilities associated with CCS, in contrast to the UK's experience with nuclear power, it will be important to provide absolute clarity at the outset on the treatment of the costs and environmental responsibilities resulting from CCS, and how those costs and responsibilities will be allocated between CCS operators and the Government.

Our suggested framework for the treatment of long-term CO₂ storage liabilities would be that the Government should underwrite or take direct responsibility for the long-term liabilities once the CO₂ has been officially recorded as being placed in storage. For their part, CCS operators will ultimately carry a significant amount of investment risk on the initial CCS investment and incur all costs through the CCS value chain until final storage

For short-term liabilities for CO₂ which would arise at various points in the CCS chain, the risks associated with on site storage of CO₂ in the period after capture and in the subsequent transportation of CO₂ are acceptable and no more challenging than those currently managed in the transportation of natural gas and liquefied natural gas into the UK system.

In terms of public acceptance, a Government sponsored communication process on the national safety, environmental, and potentially economic benefits of CCS should be undertaken once policy has been established.

From a public health and safety standpoint it will be important to recognise that, whilst there are certain similarities between the long-term liabilities associated with the storage of CO₂ and nuclear waste, the ultimate consequences of a fundamental failure of a CO₂ storage facility such as a reservoir or saline aquifer will be significantly less serious than a similar leakage of nuclear material. The contribution CCS can make to the UK's long-term carbon reduction targets will clearly need to be communicated, and can support the UK's position as a world leader in the development of sustainable energy sources via carbon abatement technology.

Local support for CCS facilities should be underpinned by the economic benefits resulting from the presence of environmentally friendly power generation in the local community, which may replace or extend the economic life of conventional power generation and provide continued employment and new employment opportunities locally.

In the context of a new era of high commodity prices worldwide, public messaging may need to address the cost to end consumers of low carbon technologies such as renewables and CCS. Consumer perceptions of energy prices will however, in all probability, be determined by factors such as movements in global commodity markets more than by the fiscal policy measures adopted to stimulate the investment in CCS.

6. Cost

Question: What are the costs currently associated with the development of different potential CCS technologies and forms of deployment? How might these costs change over time and what is the evidence for any estimates of this? How might changes in the relative prices of coal and gas in the framework governing emissions of CO₂ and other pollutants affect the costs and probability of CCS? To what extent

does EOR reduce costs and increase the commercial viability of CCS? How does EOR using CO₂ compare in cost terms to EOR using other means? 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? What are the costs associated with building capture-ready plant and how do they differ from the cost of constructing fully operational CCS facilities? To what extent can any additional costs be mitigated by decisions on design, location, etc? Is the use of CCS currently a profitable option for businesses in the electricity supply sector and other sectors and, if not, what is the shortfall? Under what conditions might it become profitable?

To date ScottishPower has not undertaken in depth internal analysis of the costs associated with the development of CCS technology. Our views of the relative economics of CCS and other low carbon technologies are therefore framed by reference to industry reports and specialist publications which have been commissioned worldwide over the last few years.

The economics of CCS technology will be driven by a number of factors, including initial capital construction costs, relative station efficiency, plant fuel costs (which are in large part driven by movements in volatile world commodity markets), ongoing operation and maintenance costs and, importantly, by the cost of carbon.

Capital costs for CCS technology remain in general more expensive than for conventional plant. Construction cost for CCS plant are difficult to determine given the lack of commercial scale application to date, but based on publicly available information could conceivably be around £1,000/kW, compared to £400 - £450 / kW for a conventional CCGT station, although it is likely that CCS costs have a wide range of possible outcomes.

A recent report commissioned by Scottish Enterprise indicated the total cost of the CCS component of a new power plant investment could be in the region of £22 - £27/tonne CO₂ for storage in depleted gas reservoirs and £28 - £35/tonne CO₂ for enhanced oil recovery. Clearly this cost is significantly in excess of the current market price of emitting carbon, which has fluctuated between €11 (£7) and €30 (£20) / tonne over the last three months.

Primarily as a result of the additional initial up front capital cost and from the incremental cost of providing full capture, transportation and storage capabilities, it is our view that CCS is not yet fully competitive with conventional power generation. Our view of generation cost for an IGCC plant with full carbon capture is in the range £36 – 60 /MWh but is highly dependent on the ultimate capital cost of the technology and assumptions around the future price of carbon.

The relative immaturity of the technology, the lack of a robust legislative and regulatory framework, and the lack of long-term clarity on the future value of carbon represent, for now, an unacceptable risk profile to allow power generators to undertake full-scale commercial application of the technology. It is currently inconceivable that development of a new power plant with CCS capability would be a profitable endeavour for power generators.

It would be expected that the capital and operating costs associated with CCS would fall over time as the technology becomes more commonly applied worldwide. In addition, the carbon costs of transportation and storage should become more predictable over time as policy frameworks are developed, and these costs could be reduced by locating CCS facilities in close proximity to appropriate geological sites of sufficient scale.

At present, given volatility in UK wholesale gas prices, which are in part driven by supply / demand fears and market sentiment, conventional coal generation is more economic than

for power generation than gas fired plant. In a world of sustained high gas prices it is conceivable that the economics of CCS investment will improve and be more closely aligned with the cost of generation from CCGT.

Under certain circumstances it is conceivable that the use of EOR can improve the economics of CCS, by providing an alternative revenue stream in the form of increased yield (by between 5 – 10%) from depleting oil and gas reservoirs reaching the end of their economic lives. In the current climate of high global commodity prices this increased revenue could have a potentially significantly positive impact on the investment case for CCS.

It is important to note however that this outcome would be considered as a best case scenario and there could be a whole host of factors (fuel recovery may not be fully effective or cease to be effective, all fields will not be suitable, field may be at wrong stage of life cycle, supporting infrastructure not suitable) which would impair the economic viability of such projects.

The use of CO₂ injection for EOR is one of several techniques for oil recovery. Other methods of recovery include:

- Water injection;
- Methane gas injection;
- Steam treatment;
- Acid treatments with or without a reservoir fracturisation process.

The technical and commercial merits of each technique are largely site dependent and it is not appropriate to generalise on the relative costs of each method in the absence of a more detailed understanding of individual projects.

It is likely that the use of EOR will be appropriate in certain circumstances on the UKCS, but we would defer to expert bodies such as the United Kingdom Offshore Operators Association (UKOOA) on this point. It is clear that not all fields will be suitable for the deployment of EOR techniques, and it will be most naturally applicable to fields approaching the end of their useful economic lives as a means of improving field economics.

In terms of the economics of capture ready plant relative to CCS, it is our understanding that whilst the cost of developing a new capture ready IGCC plant would be almost double the cost of a conventional coal plant, the incremental expenditure to take the capture ready plant to full CCS is relatively modest (perhaps a further 20 – 25% cost uplift). In theory, the transformation of conventional power generation plant to incorporate capture ready design is primarily a matter of plant configuration, and whilst this process will add to the cost of the new plant, it should subsequently reduce the cost of retrofitting CO₂ capture equipment.

The merit in encouraging the development of capture-ready designs (as opposed to full CCS deployment) in the UK for adoption as replacement for aging UK coal plant over the next 10 – 15 years will in large part be determined by the pace and urgency at which Government intends to deliver the long term carbon reduction policy goals.