# Carbon choices – options for demonstrating carbon capture and storage in the UK power sector

WWF-UK

**May 2009**

## Summary

The UK power sector is currently responsible for more than a 30% of our $CO_2$ emissions - a high proportion of which (around 70%) comes from burning coal[1]. Utilities are now showing strong interest in a new generation of coal-fired power stations – presenting a huge challenge to the UK's prospects of meeting emission targets and its aspirations to show global leadership.

The Committee on Climate Change recently advised that the Government should aim to ensure that the power sector is almost completely carbon-free by 2030. Indeed, achieving this goal – and particularly dealing with the threat of unabated coal stations – is one of the most important contributions the UK could make to tackling climate change globally.

Carbon capture and storage (CCS) is widely touted as an option which could play a bridging role in reducing emissions from burning coal and gas in the transition to a truly low-carbon, sustainable energy system. However, the technology has yet to be proven at commercial scale.

In April, the Government announced plans to push forward with up to four CCS demonstration projects and to require some level of CCS on all new coal-fired power stations. However, the details of how this policy will be applied in practice could make a big difference to the UK's carbon emissions, and to the strategic development of CCS.

WWF commissioned IPA Energy + Water Economics to look at the potential impact on $CO_2$ emissions of demonstrating so called post-combustion[2] carbon capture on up to 300MW of the existing 2,400MW subcritical power station at Longannet in Scotland, and on a new 1,600MW supercritical coal plant (the size of the new power stations proposed at Kingsnorth in Kent and Tilbury in Essex). These plants have all been entered into the existing CCS demonstration competition, and the Government has said that it expects demonstrations to be of 300MW net capacity.

IPA Energy + Water Economics found that building a new supercritical coal plant fitted with only 300MW of carbon capture capacity could increase $CO_2$ emissions from the power sector by 32 million tonnes between 2014 and 2025. This is roughly equivalent to running an extra four-and-a-half coal power plants for a year. Conversely, using the existing station at Longannet to test carbon capture could result in a net decrease in emissions over the same period of 14.5 million tonnes, roughly equivalent to the emissions that would be saved if you switched off two coal fired power stations for a year.

The Government has suggested that CCS might be required to be fitted on the full generating capacity of all new coal plants by 2025, on the basis that by then the technology will have been "*technically and economically proven*". However, in the absence of strict, enforceable conditions there is no guarantee that full-scale CCS retrofit will actually happen. Moreover, if the technology proves technically or economically challenging it is not clear whether the Government will require early closure of any new coal plant.

A new 1,600MW plant built in 2014 could be expected to operate for 40 years or more. If such a station continues to operate with just 300MW of CCS capacity, IPA Energy + Water Economics found that it is likely to pump out nearly 240 million tonnes of $CO_2$ over this period. Or to put this another way – without strict guarantees that any new power station must be completely equipped with CCS by the early 2020s (as recommended by the Committee on Climate Change), then the current Government proposals could allow roughly 80% of its lifetime $CO_2$

**1** "Building a low-carbon economy – the UK's contribution to tackling climate change" chapter 5, decarbonising electricity generation, December 2008 http://www.theccc.org.uk/pdf/7980-TSO%20Book%20Chap%205.pdf
**2** Post-combustion technology works by capturing the $CO_2$ emissions from the gas stream once the fuel has been burnt.

emissions to end up in the atmosphere. Technical problems, or claims that full-scale CCS would entail excessive cost, make this an all too plausible outcome.

In light of these significant risks, WWF believes that there are more credible ways to accelerate demonstration of CCS while still reducing emissions:

- Post-combustion carbon capture technology can be deployed relatively rapidly on an existing coal plant, such as Longannet, without incurring the risks of high-carbon lock-in to new, large-scale coal investments.
- In parallel, WWF believes that a focus on pre-combustion[3] technology – where new stations could have full-scale CCS from the outset – could also have an immediate beneficial impact on power sector emissions if plants replace more carbon intensive plant.
- In addition to making the right strategic choices in demonstrating carbon capture there is clearly a need for greater regulatory certainty to prevent lock-in to new largely unabated high carbon infrastructure whilst CCS remains an unproven technology. To address this WWF recommends that a plant-based emissions performance standard of 300g$CO_2$/kWh – the level achievable by a new gas plant with reasonable use of waste heat – should be applied immediately to all new power plant. This limit should be tightened to around 150g$CO_2$/kWh (for both new coal and gas stations) by the early to mid 2020s, in order to deliver the Committee on Climate Change's recommendations. Likewise, existing power stations should be required to meet an emissions performance standard of 300g$CO_2$/kWh by 2025 at the latest in order to reduce emissions and provide a level playing field for investments in new, cleaner technology.

## Introduction

The Royal Assent of the Climate Change Act last November, which set in statute a binding commitment for the UK to cut its greenhouse gas emissions by at least 80% (below 1990 levels) by 2050, is a significant achievement. But it is now vital to ensure that the Act truly helps guide a rapid transition to a low-carbon economy in the UK. This will require the establishment of a robust plan, with a clear package of policies and measures, setting out how the UK will comply with the carbon budgets and to ensure the 2020 and long-term emission reduction targets are met.

One of the most critical elements must be a plan which drives rapid low and zero carbon investment in the power sector. The Government's Committee on Climate Change made clear that the power sector should be almost completely decarbonised by 2030, and also made clear that robust regulatory measures above and beyond the inclusion of the sector in the EU Emissions Trading Scheme are needed to ensure delivery of this outcome[4].

Alongside significant investment in renewable energy technologies and energy efficiency measures, carbon capture and storage (CCS) could potentially play a bridging role in reducing emissions from burning coal and gas in the transition to a truly low-carbon sustainable energy system. However, the full chain of CCS - which involves capturing $CO_2$ from burning or gasifying fossil fuels and then transporting it to underground storage sites (probably in depleted oil and gas reservoirs or in saline aquifers beneath the North Sea) - has yet to be proven on a large scale.

**3** Pre-combustion technology (which involves gasification of the fuel before it is burnt, separating out the $CO_2$ from $H_2$ and other gases and burning the $H_2$ to generate energy) is integral to the engineering design and construction of the plant itself and therefore it is envisaged that at least 90% of $CO_2$ emissions from the full generating capacity can be captured from the start.
**4** The recent report from the UK's Committee on Climate Change "Building a low-carbon economy – the UK's contribution to tackling climate change" from December 2008 noted that "*Any feasible path to a 80% reduction by 2050 will require the almost total decarbonisation of electricity generation by 2030*" "*There is a strong case for buttressing the carbon price lever by establishing a clear and publicly stated expectation that coal-fired power stations will not be able to generate unabated beyond the early 2020s*".

Until recently the Government has seen the UK's role in contributing to an EU wide programme to demonstrate CCS as being taken forward through its so-called CCS competition. This competition was intended to fund just one project of up to 300MW, which might not be fully up and running until the end of the next decade. At best, the competition could be described as painfully slow-moving – at worst it appeared to be being used as a way to justify consent for a new generation of largely unabated coal fired power plants.

However, on 23rd April Ed Miliband, Secretary of State for Energy and Climate Change, proposed that up to 4 projects of 300MW would now receive funding – giving hope that the UK may be moving away from the era of unabated coal, and towards a more credible CCS demonstration programme[5].

This short report is intended to assist the Government in making the right decisions about CCS demonstration and deployment – to ensure rapid and strategic demonstration of the technology, while also delivering real emissions reductions and avoiding lock-in to new largely unabated coal fired power stations. WWF commissioned IPA Energy + Water Economics to undertake an assessment of the $CO_2$ emissions that would result from the current UK CCS demonstration competition entries, which include proposals from companies to fit post-combustion carbon capture technology to both new and existing power stations. A summary of the results is presented here[6].

## Recent history of the UK's involvement in CCS and the UK competition

The UK has played a major role in, for example, amending international marine treaties to allow for the storage of $CO_2$ and in designing EU legislation on CCS. However, to date the same cannot be said for the UK's domestic implementation of demonstration projects. Progress has been slow since 2005 when the G8 international leaders' summit (chaired by the UK) championed CCS.

It wasn't until November 2007 that the UK Government launched its CCS competition which allowed utilities to bid for substantial funds, expected to be in the region of £1 billion, to cover the capital and operating costs of just one commercial scale CCS plant[7]. The initial phase will deliver CCS capacity equivalent to 50-100MW by 2014, rising to 300-400MW "*as soon as possible thereafter*".

This came too late for several early projects including BP and Scottish and Southern Energy's proposal from 2005 to capture $CO_2$ from a gas plant at Peterhead. BP pulled the plug on this project[8] claiming that it could have started operation in 2009 had it been given the green light earlier. Indeed a recent report notes: "*BP provided the UK Government with a ready-made CCS package. However, nothing happened. The Government let the opportunity slide away, and with that, gave up leadership in CCS projects.*"[9]

Moreover, the CCS competition was restricted to "post-combustion" capture technology which disappointed companies such as Centrica, who had proposed to install full-scale "pre-combustion" CCS on an advanced coal gasification plant. The decision to focus on post-combustion technology, and the Government's insistence that "carbon capture readiness" was a

**5** "23rd April 2009 – Press Release – No new coal without CCs – Miliband" http://www.decc.gov.uk/en/content/cms/news/pn050/pn050.aspx

**6** The full analysis by IPA Energy + Water Economics - "Assessment of $CO_2$ emissions from UK Carbon Capture and Storage Demonstration Competition entries", Data Analysis for WWF-UK, April 2009 - is available on request.

**7** http://nds.coi.gov.uk/environment/fullDetail.asp?ReleaseID=331669&NewsAreaID=2&NavigatedFromDepartment=True

**8** An identical plant developed by BP is now due to be in commercial operation in Abu Dhabi by 2012.

**9** "Six thousand feet under – burying the carbon problem" Stuart Hazeldene and Gil Yaron. Policy Exchange, 2008. http://www.geos.ed.ac.uk/research/subsurface/diagenesis/Six_thousand_feet_under_Policy_Exchange_390_Haszeldine_08.pdf

meaningful concept, contributed to a “build now, capture later” mindset amongst the UK power industry.
In June 2008 the Government announced which bidders had been successful in pre-qualifying for the competition[10]. Following the subsequent withdrawal of BP’s entry to the competition and RWE npower joining one of the successful groups, the remaining bidders are:

- E.ON UK Plc – with their controversial proposed new 1,600MW supercritical coal fired power station at Kingsnorth, Kent (a replacement for the existing 1,940 MW power station which is due to close in 2016). This would consist of two new, relatively efficient 800 MW coal units[11];
- RWE npower, Peel Energy and DONG Energy – with plans to build a new 1,600 MW supercritical coal fired plant at Tilbury in Essex; and
- Scottish Power Generation Limited and Marathon Oil – with plans to fit carbon capture equipment to part of the existing 2,400 MW subcritical coal plant (comprising four 600 MW generation units) at Longannet, Fife[12].

The Government announcement in April suggests that it intends to proceed with the competition but that it will also potentially look to fund up to three further demonstration projects of 300MW in size[13] which will be chosen via a competitive process. Pre-combustion CCS demonstrations have now been brought back into the mix of the technologies the Government will consider funding.

## Impact of current CCS competition entries on power sector $CO_2$ emissions taking into account the implications of the recent Government announcement on coal

WWF commissioned IPA Energy + Water Economics to undertake an assessment of the $CO_2$ emissions that may result from the current UK CCS demonstration competition entries using their macroeconomic generation market model – ECLIPSE (Emissions Constraints and Policy Interactions in Power System Economics). The following five cases which relate to the successful bidders listed previously were considered:

- Existing 2,400MW subcritical coal fired power station at Longannet (36% efficient).
- Longannet with 300MW CCS retrofitted on one unit from 2014.
- A new supercritical 1,600MW coal fired station (44% efficient) without CCS – providing illustrative figures for either the RWE npower etc. or E.ON UK Plc power stations in the case that they do not win the competition.
- A new supercritical 1,600MW coal station with 300MW CCS fitted on one unit from 2014 - again representing either the RWE npower etc. or E.ON UK Plc projects.
- A new supercritical 1,600MW coal station with 50 MW CCS from 2014 increased to 300 MW from 2020 - again representing either the RWE npower etc. or E.ON UK Plc projects.

The following assumptions were made with regards to the technical and operating characteristics of the CCS plant and constraints of the competition[14]:

- CCS is estimated to consume one-third extra power (i.e. 300MW CCS takes 400MW from the unabated unit[15]) thereby reducing the total available net electricity output.

---

**10** http://nds.coi.gov.uk/environment/fullDetail.asp?ReleaseID=372398&NewsAreaID=2&NavigatedFromDepartment=True
**11** http://pressreleases.eon-uk.com/blogs/eonukpressreleases/archive/2008/03/31/E.ON-enters-UK-Government_2700_s-Carbon-Capture-and-Storage-competition.aspx
**12** We understand that the proposed “repowering” of the plant has now been put back towards the end of the next decade.
**13** Requiring around 400MW of generation capacity.
**14** Additional assumptions with regards to the market context, commodity prices and market development are available on request.
**15** In line with the current UK Government announcement.

- Efficiency is reduced by 10 percentage points from the capture process for the abated portion of the unit[16]. The efficiency of new plant is therefore reduced to 34%, and Longannet to 26%.
- That the unit of the plant fitted with CCS operates at a minimum annual load factor of 85% as mandated by the CCS competition rules and that this constraint is applied to the unabated portion of the unit as well. This is likely to result in a greater running time than would be dictated by pure economics, thus displacing more cost-efficient but potentially higher carbon generation.
- CCS captures 90% of the $CO_2$ produced.

The results were as follows:

**Impact on emissions from the power sector to 2025:**

The baseline case scenario of emissions from the power sector used by IPA Energy + Water Economics assumes that any new coal plant would displace investment in new gas plant (which they assume would dominate the long-term generation mix out to 2025)[17]. It also includes the assumption that the existing plant at Longannet is not fitted with any carbon capture technology.

Under these assumptions retro-fitting the plant at Longannet with 300MW CCS acts to reduce the overall emissions from the power sector by 14.5 million tonnes (Mt) of $CO_2$ below the baseline over the 12 year period between 2014 and 2025 (see Table 1). This is roughly equivalent to the emissions that would be saved if two coal fired power stations were switched off for a year.

Fitting the equivalent capacity of CCS to a new 1,600MW coal plant in 2014 may result in an increase of 32.4Mt $CO_2$ from the power sector over the same period[18]. If CCS implementation were staged, so that only 50MW were initially fitted to a new plant in 2014, rising to 300MW by 2020, then emissions would increase by 40.9Mt $CO_2$ – or roughly equivalent to the emissions from running five-and-a-half coal fired power plants for a year.

**Compared to the option of demonstrating CCS on a new coal station, awarding the CCS demonstration to Longannet would reduce $CO_2$ emissions by some 47 million tonnes – or potentially some 55 million tonnes – over the 12 years between 2014 and 2025.**

**Table 1: impact on $CO_2$ emissions from the power sector between 2014 and 2025 compared to the baseline case emissions (which includes an unabated Longannet)**

| Scenario | Impact on $CO_2$ emissions (million tonnes) |
|---|---|
| Longannet with 300MW CCS from 2014 | - 14.5 |
| New coal with no CCS | + 53.1 |
| New coal with 50MW CCS from 2014, 300MW in 2020 | + 40.9 |
| New coal with 300MW CCS from 2014 | + 32.4 |

As a sensitivity test IPA Energy + Water Economics also looked at the impact on overall power sector emissions if a new 1,600MW coal plant with 300MW of CCS demonstration displaced investment in zero-carbon renewable energy instead of gas plant. In this case, overall power sector emissions over 2014 to 2025 would be 82.6Mt $CO_2$ higher than if the investment had gone to renewables.

**16** This is within the IEA's estimated band of 6-12%.
**17** Although this baseline case shows emissions from the power sector falling between 2014 and 2025 this fall is far short of the reduction required to meet the recommendation from the Committee on Climate Change that the sector should be almost completely decarbonised by 2030.
**18** If it is assumed that investment in a new coal plant means that new gas capacity does not get built.

**Impact on lifetime emissions of individual power plant:**

In the recent announcement the Government proposed that "….*new coal power stations should retrofit CCS to their full capacity within five years of CCS being independently judged technically and economically proven. We will plan on the basis that this will occur by 2020*."[19]

However, it remains far from clear whether there will be any credible guarantee that a full-scale CCS retrofit would be required to any new station taking part in the UK's competition (or the wider demonstration programme recently announced) by 2025. This raises the concern that high emissions could continue for many decades if CCS technology is deemed to be not technically or economically proven.

IPA Energy + Water Economics calculated the lifetime emissions from a new 1,600MW coal plant, similar to the plants being proposed by RWE npower etc. and E.ON, if CCS coverage remained low. The results (see Table 2) showed that an additional **239-249Mt $CO_2$** could enter the atmosphere over the 40 years of the plants life if CCS coverage only remained at the level required by the competition (300MW) and was not scaled up to cover emissions from the whole of the plant. Emissions could be higher still if the demonstration plant proved unsuccessful yet the station was allowed to continue operation without it.

**Table 2: impact of fitting partial CCS on lifetime $CO_2$ emissions from individual plant in the competition**

| Scenario | Potential lifetime emissions of plant ($MtCO_2$) | Percentage of emissions not captured |
|---|---|---|
| 2,400MW Longannet with 300MW CCS from 2014 | 106.7 (up to 2025 when Longannet may close) | 92% (between 2014 and 2025) |
| 1,600MW new coal with 50MW CCS from 2014, 300 MW in 2020 | 248.8 (40 year life span) | 83% (40 year period) |
| 1,600MW new coal with 300MW CCS from 2014 | 238.7 (40 year life span) | 80% (40 year period) |

To put this another way – even the recent Government proposals may still result in nearly 80% of the lifetime emissions from a new 1,600MW plant (e.g. the size of new plant proposed at Kingsnorth) being emitted to the atmosphere if they fail to introduce binding and effective guarantees that CCS retrofits would occur such as a plant based emissions performance standard[20].

In contrast, the risks of high-carbon lock-in are more constrained if CCS is deployed on an existing plant such as Longannet, which could be expected to operate in any case without any abatement. In addition another potential benefit to this is that any decision to invest in replacement coal generation capacity would then be informed by real experience with CCS. Scottish Power is investigating options for "repowering" Longannet towards the end of the next decade – this would mean that the station would effectively become a "new" plant, with a long life expectancy. WWF believes that a repowered Longannet should be fitted with full-scale CCS from the outset.

**19** "Building a low carbon economy: a framework for the development of clean coal" DECC, April 2009, http://www.decc.gov.uk/Media/viewfile.ashx?FilePath=What we do\UK energy supply\Energy mix\Carbon capture and storage\1_20090423122221_e_@@_frameworkdevelopmentcleancoal.pdf&filetype=4

**20** An emissions performance standard (EPS) would set a limit on $CO_2$ emissions from power stations measured in grams of carbon dioxide per kilowatt hour (kWh).

## Conclusions and recommendations

The coal fired power station at Longannet in Scotland is an ageing, inefficient plant which has contributed to the legacy of $CO_2$ emissions from the power sector for the last 37 years. However, demonstrating post-combustion CCS technology on this and other existing conventional coal power plant would at least help to reduce the impact on UK $CO_2$ emissions in the last years of their operating life – as well as providing a relatively speedy, and lower risk, route to demonstrating the technology.

Conversely, with no guarantee that full scale CCS retrofit will ever take place demonstrating post-combustion CCS on only a small part of a new supercritical plant, such as that proposed at Kingsnorth or Tilbury, could substantially increase emissions from the UK power sector for many years – and potentially many decades.

WWF therefore makes the following recommendations to the UK Government:

**With regards to demonstrating CCS:**

- Seek to demonstrate post-combustion carbon capture technology on existing coal plant. This will generate some limited, but useful, emission reductions and avoid the lock-in risk of new high carbon investment.
- Strongly prioritise pre-combustion capture and gasification technology for any new coal plants. The Government should ensure that integrated gasification combined cycle (IGCC) plants which test pre-combustion technologies capture at least 90% of $CO_2$ emissions from the full generating capacity from day one. This is possible because IGCC plant tend to be smaller than supercritical plant, and because pre-combustion technology is integral to the engineering design and construction of the plant itself. Full-scale CCS coverage is therefore the only sensible option[21].

**With regards to wider UK energy policy:**

- Focus on putting in place the policies and measures required to ensure that the Government's existing 2020 energy efficiency and renewable energy targets are met, and preferably exceeded.
- Bring forward as soon as possible a plant-based emissions performance standard, similar to the model already in force in California and similar to the limit values already used in IPPC permits to control other pollutants. This should be set at a level of 300g$CO_2$/kWh for all new plant from now on, and tightened to 150g/kWh by the early-mid 2020s. All existing coal and gas power plant should also be required to comply with an emissions performance standard of 300g/kWh by 2025 at the latest. This policy framework would deliver the recommendations of the Climate Change Committee regarding decarbonisation of the power sector, and would ensure that the UK remains on track to meet its carbon budgets under the Climate Change Act.

**21** This was acknowledged in an email from Michael Jacobs, Special Advisor to the Prime Ministers to NGOs sent on 27th April following the UK Government announcement on coal which said "*Where pre-combustion technology is used, all (90%) of the $CO_2$ emissions from coal will be captured from the beginning - the technology can only operate this way. So there is no question of partial CCS to start and retrofit later. All coal use will have the $CO_2$ captured from the beginning*."