Current Development of Carbon Capture and Storage in the UK – a Non Technical Review

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Abstract:

This paper reviewed a current situation of carbon capture and storage (CCS) development in the UK mainly within the last 10 years in general. It looked at the positive ways to implement the CCS technologies, including the geological advantages, potential sector growth, financial incentives, and the support in the policies. Current projects were brought forward together with the university and industry research. Some concerns and limitation of applying CCS technologies were discussed. To the end, the conclusion was made that the UK is in a good position to implement CCS technologies and would become a global leader in CCS development providing that the first four trials were successful.

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1. Introduction

The release of carbon dioxide (CO_2) into the earth's atmosphere from the burning of fossil fuels is considered to be the main cause of climate change and global warming. In just over 200 years the amount of carbon dioxide in the atmosphere has increased by 30% [1] and the UK emitted more than 500Mt (million tonnes) of CO_2 per year averagely within the latest 20 years. The annual CO_2 emission in the UK has increased when the industrial revolution (1800's) started and it reached peak in 1980's. Statistics data from the Department of Energy and Climate Change showed that this emission rate started to decrease gradually from 589.7 Mt in 1990 to 491.7 Mt in 2010.

The problem has been widely accepted by governments with many recognising a need to mobilise an urgent response to reduce greenhouse gases in line with commitments made at the Kyoto Protocol. The 2003 Energy White Paper [2] sets the target of a 60% reduction in UK emissions of the greenhouse gas CO_2 to about 240Mt by 2050 from 550Mt in 2000.

There are a variety of mechanisms proposed to achieve this target: improving energy efficiency, use of renewable energies, nuclear power and so forth. It is not sustainable to achieve one without the other. However the likelihood that fossil fuels will be made redundant altogether is highly improbable because by 2030, world primary energy demand is expected to increase by 61% or so, of which fossil fuels continue to meet more than 80% of demand [3]. Thus, in moving toward a low carbon economy, consideration to the management of carbon produced as a by-product of gas, oil and coal-based power production is a necessity. One such method is via Carbon Capture and Storage (CCS) technologies, which involve capturing the carbon dioxide emitted, and transporting and storing it in secure spaces. Carbon dioxide capture technologies are based on three generic approaches: pre-combustion, post-combustion and oxyfuel [4] and can be applied to coal or gas-fired power generation, coal gasification, steel manufacture, refineries and petrochemical processes, and hydrogen production etc.

The UK is in a strong position to lead in the development of CCS technology and to gain large commercial and social benefits from its deployment because of a) geological formations; b) strong capabilities in offshore engineering, oil and gas extraction and the geological sciences; c) an existing infrastructure to support offshore CO_2 storage operations [4]. However in recent years the UK has failed to make the advances required in CCS technology. This may be partly due to the 'bling' factor of renewable technologies capturing the hearts and minds of scientists, entrepreneurs, developers, government officials and most importantly the public, but the failure to drive advances forward is also largely connected to the problems encountered in developing large scale CCS plants.

Therefore this paper is to review the UK current situation towards the CCS development, its perspective, financial incentives and policy which affect its future development.

2. The UK and CCS – Where are we now?

Fossil fuels play a vital role in providing energy not only in the UK but also globally. In the UK, they are obviously part of a diverse and secure energy mix but in order to avoid dangerous climate change, it is urgent to reduce CO_2 emissions for these sources in a sustainable way. Development and deployment of CCS is critical to this, as it has the potential to reduce the CO_2 emissions from power plants by around 90% [5], and its success would make a significant contribution towards the UK and international climate change targets.

MARKAL modelling analysis by BERR (Department for Business, Enterprise and Regulatory Reform) showed that CCS could play an important role in delivering the UK's CO_2 reduction targets [6]. The power generation and hydrogen production need to deploy CCS to abate CO_2 emissions commencing between 2010 and 2020. The achievement of CO_2 capture would be 10-25Mt/yr typically in 2010-2020 increasing to 100-150Mt/yr in

2040-2050, though there is no targeted reduction percentage by CCS released yet. From the model, CCS could provide cost effective back-up to intermittent sources such as wind and solar power, and complement the deployment of renewable energy [4].

The UK's Energy White Paper 2007 [7] provided details of a demonstrator competition launched in November 2007 by the Department of Energy and Climate Change. The demonstration will be one of the first of its kind and is on course to demonstrate the full chain of CCS by 2014 and its principle aim is one of placing the UK as a world leader in this field. It is hoped the technology will be transferable to other markets, particularly in emerging economies. The first trial utilising CCS technology at a UK power stations is currently taking place at Scottish Power's Longannet facility in Fife, Scotland. The trial which incorporates a post-combustion capture method is one of the competitors in the £1 billion government competition. A 30-tonne test unit is used as the basis of the trial and will process 1,000 cubic metres of exhaust gas per hour [8, 9]. Chemicals are used to remove CO_2 from a huge chimney and it turned into a liquid form, ready for underground storage. The initial aim of the trial was to monitor and analyse the data given out in order to obtain a full understanding behind the science involved. The eventual aim however is to use the trial as a pilot to build a full scale demonstration project that will capture about 90 per cent of the carbon dioxide that is emitted. The significance of the trial, if successful, is that it is clear evidence that CCS technology can be retrofitted to existing power stations throughout the UK and the world.

The UK government is currently sponsoring other two commercial scale demonstration projects similar to Longannet. These are:

a) Npower: Feasibility study of 1000MW + CCS in Tilbury , Essex

b) E.ON: Potential new coal plant in Kingsnorth, Kent

Together with EU funded CCS demonstration plant in Hatfield coal-power station, Yorkshire [10], there are now four CCS projects, which will be the main source of learning and experience of different CO_2 capture technologies in the UK.

The DTI and DEFRA [4] published a detailed strategy for the role out of CCS in the UK, which addressed the future requirements for reducing CO_2 emissions from fossil fuel power generation. It aims [11]

a) To ensure the UK takes a leading role in developing and commercialising carbon abatement technologies;
b) To enable cleanly-used coal to have a role in a sustainable world;
c) To make other fossil fuels more environmentally friendly;
d) To include no new coal without CCS, and a long-term transition to clean coal.

The UK Government has a legally binding framework to tackle climate change, including a target to cut emissions by 80% by 2050 and a set of five-year carbon budgets to chart the course and keep the UK on track [12]. It is predicted that over half of the emissions savings needed to meet our first three carbon budgets will come from power and heavy industry and, as we continue on the pathway to meeting our 2050 goals, our electricity sector will need to be almost completely decarbonised [13].

Looking to the next five years and beyond the DECC-funded demonstration programme the UK Government expects that CCS should be able to compete with other low carbon energy generation options. The government's ambition is to accelerate the commercialisation of CCS with the technology ready for wider deployment from 2020 [13] though it is recognised that this will be very challenging and that business will need to take account of a degree of timing uncertainty when assessing opportunities.

3. Opportunities

3.1 Geological advantages

a) Oil and gas fields

The UK has many emptied or nearly emptied oil and gas fields, which are perhaps the cheapest and most effective locations to store CO_2. A study in 1996 estimated that there will be space for about 5.3 Gt CO_2 in depleted oilfields, and about 11-15 Gt CO_2 in depleted gas fields. This is about 10 years of total UK CO_2 emissions in oilfields, and a further 30 years in gas fields [13].

b) Saline aquifers

These are porous rocks deep below ground that are full of salty water. Studies [13] showed that using the saline aquifers, UK could store 19-716 Gt CO_2, which was equivalently total UK CO_2 emission for 500 years. But there is less knowledge and more risks with this geological store. Research showed that they are similar to oilfields [14] and worth investigating further and there is a test site using a saline aquifer for underground CO_2 storage in the North Sea, which is located above the Norwegian Sleipner Field.

In general, the UK deep offshore has a massive storage potential that is big enough to store 100 years of emissions from all power plants in NW Europe [15]. This provides the UK with a huge potential to sell its storage capacity which is estimated to be worth in the region of €5bn a year for 50 years.

3.2 Sector growth

CCS development within the UK has been mainly targeted at large energy generation sources such as power stations and industrial plants where the greatest potential to reduce CO_2 emissions exists. And the UK is looking to take a leading role of CCS development throughout Europe and the World. An evidence saw a launch of the Carbon Capture and Storage Association in

March 2006 , which brought together specialist companies in manufacturing, power generation, engineering, oil, gas and minerals. It was welcomed by then government. Experts in the relative industries [16] believed that UK is in a strong position and stands a good change to run CCS projects in the aspects of finance, consultancy and regulations.

In 2007-08 the UK's market for CCS technologies was £468m out of £13.28bn of international market (3.5% share) [17]. But it is expected to see a big potential of expansion by around 4% increase a year between now and 2015 as there are European funding mechanisms available for the demonstration power plants. This potential provides a huge opportunity for the established engineering companies to get involved in the complex power plants, gas/oil supplier, compressor and pipeline etc. Obviously geological consultancies will be big players in prospecting for suitable storage sites and some of those companies are already working on the basic approaches to the technology.

3.3 Financial Incentives

Under current market conditions, the wide scale deployment of CCS by industry is unlikely. Even with the cost offset associated with Enhanced Oil Recovery / Enhanced Gas Recovery (EOR/EGR), the uncertainty and business risk around CCS deployment mean the industry is unlikely to take to the technology rapidly without viable incentives.

a) Direct Government Subsidy: Government co-funding for early appraisal activity, testing and demonstration is a necessity and is currently under review. In this method, government will pay a company the cost difference between the price of building a new conventional fossil-fuel power station and the one with CCS [18]. The government will also cover the difference in operating costs. This is what the UK Government is using for the first UK CCS demonstrators as detailed earlier.

b) Tax CO_2 Emissions: CO_2 emissions to the atmosphere have their values, resulting in that it might be cheaper to capture and then store the CO_2. Good examples are CO_2 storage project at the Sleipner field which was under the scheme of Norway's carbon emission tax, and US EOR projects which benefited from tax incentives [19].

c) EU Emissions Trading Scheme: There is also long-term potential to gain credit for the offset CO_2 via the EU Emissions Trading Scheme. To do this would require the development and agreement of inventory methods to monitor, report and verify the CO_2 savings achieved, to comply with the Kyoto Protocol [20].

d) Cap and Trade Programme: This is an environmental political tool which "delivers results with a mandatory cap on emissions while providing sources flexibility in how they comply. Successful cap and trade programs reward innovation, efficiency, and early action and provide strict environmental accountability without inhibiting economic growth" [21]. Europe (including the UK) "has stuck with Cap and Trade because of its cost-effectiveness and its ability to deliver an environmental outcome" [22].

3.4 Policy

Policy is playing a crucial role in the development of CCS in the UK. Clear and positive direction started to emerge with the former Labour Government's announcement that there would not be new coal power stations built in the UK "unless they captured and stored at least a quarter of their greenhouse gases immediately and 100% of them by 2025" [23].

While the Conservative energy policy promised to put UK CCS back on track, bringing the current CCS competition to a rapid conclusion. It would also expand the demonstration programme to at least four facilities (including the current competition) and include both pre-combustion and post-combustion technologies [24]. Although in general Conservative policy is to offer the prospect of lower increases in bills than under current policy, funding commitments to CCS are the exception and would be maintained, as if CCS is successfully demonstrated, Britain is particularly well-placed to benefit from an international market in CCS equipment and know-how. It is also very promising to see a plan for the acceleration of CCS technology.

The Liberal Democrat Party has a strong policy for renewable technologies at present. However, it could be seen as another driving force to integrate CCS technologies into the current and new power plants as coal is still a vital part of our energy mix as mentioned before.

Although all political parties are aware of the importance of carbon abatement, and actively, but mainly in strategy , response to potential CCS projects, all the positive statements above do not mean that the funding for the future CCS projects are secured. There is no clear policy to guide the CCS project development due to the following reasons:

a) The policy makers need to review the balance of cost and benefits from first trials. They have a "wait and see" attitude.
b) There is a lack of understanding of key technologies and the associated risks. Optimum strategy could hardly be made.
c) There are few references in technical / economic analysis for CCS projects, most of which are purely project-based [25]. Popularity of the results was in doubt based on assumptions. It could be done when there were a large number of projects running in a stable and optimised condition. Bear in mind that market factors, such as high labour cost due to the labour shortage and soaring prices of raw materials, would challenge the technical/economic analysis.

4. University and industry collaboration

It was announced in May 2009 that the power supplier E.ON and the Engineering and Physical Sciences Research Council (EPSRC) had provided a strong financial support to four University-led projects investigating CCS technologies [26] in the following fields:

a) The relationship of material surface and CO_2 absorption or "soak up" rates. The universities involved are: The University of Nottingham (lead), University College London, University of Birmingham, and University of Liverpool;

b) Technical and material challenges of large-scale transportation of carbon dioxide through pipelines. The universities involved are: Newcastle University (lead), Imperial College London, University College London, the University of Nottingham, Cranfield University, , and a wide range of industry partners;

c) Further study of the oxyfuel combustion process. The universities participated are: University of Leeds (lead), University of Cambridge, Imperial College London, the University of Nottingham, Cranfield University, and University of Kent;

d) Economical analysis of large scale CCS and separating CO_2 from fossil fuel power stations. The University of Edinburgh is leading the project.

Apart from those close ties between EoN, EPSRC, and the universities involved, many main power generating companies have already set up the business links with their favoured universities, e.g. Scottish Power funding a chair in the University of Edinburgh; E.ON UK and Npower collaborating with the University of Sheffield and University of Leeds. All of the collaborative work will further explore the CCS technologies which are suitable for the commercial development in the near future.

5. Limitations of CCS deployment

There were many advantages to develop CCS technologies in the UK as stated above, but the limitations are obvious as follows:

a) Technical Risk – It is a fact that there is no commercial-scale CCS power station being developed in any country so far, despite of some achievements in key elements of the individual stages. The first four demonstrators in the UK would deliver a breath-taking achievement but with high technical risks.

b) Cost – "Each individual in the UK is approximately responsible for about 10 tons of CO_2 each year. Estimates of cost for capture, liquefaction and storage in North Sea aquifers are about 20 pounds per ton", equivalently £200/person/year [18]. It could be reduced further if greater energy efficient measures take place. Under the current economical circumstance, it would be seen as an extra financial burden for each household if the cost has to be paid by the individual person.

c) Environmental Issues – There are concerns that once captured CO_2 could be released into the atmosphere during the transportation or storage stage meaning that a careful monitoring process would be required. There are also some concerns regarding tightness of geological storage sites. A proper measurement should take place upon what damage the extraction processes may have caused after millions of years' storage underground for oil and gas.

d) Public Perception – A recent survey based around expert opinion on the understanding of large scale deployment of CCS within the UK found that without long term policy framework and costs, the implementation of CCS could develop nowhere [16, 27-30]. However it is long way to get public involved and educated, and eventually to support its implementation.

6. Conclusions

Carbon capture and storage technologies allow countries such as the UK to carry on burning fossil fuels for the near future without damaging the environment. The development of CCS in the UK is an important part of the UK's overall commitment to help tackle global issues such as climate change. The UK government feels the UK is well placed to become a global leader in CCS development. However this paper analyses some of the challenges they face if this is to be achieved. The UK economy is of a welcome boost and it is predicted that once CCS is fully deployed in the UK thousands of new jobs will be created. The UK also offers a strong experienced knowledge and resources due to the many years of extracting gas and oil. One of the main resources that give the UK an increased edge over other countries is the North Sea where CO_2 storage potential is thought to be large enough to serve not only the UK but also the rest of Europe. This could potentially lead the UK to CCS leadership throughout Europe and even on a global scale.

Public perception and cost are two of the main limitations affecting CO_2 take-off in the UK. Despite the increasing popularity of CCS, for many people CCS technology is still unheard of. Faced with increased utility bills, winning over the UK public will prove to be a big stepping stone in the development of CCS. In the absence of existing commercial scale deployment, there are also great risks associated with the technology.

To overcome this risk, trials are currently taking place at various locations throughout the UK. The trials have been set up to demonstrate the technology with the intent to have a full scale commercial plant working by 2014. The UK Government has also invested heavily in several UK Universities to study and research the technology further. Should the outcome of the research lead to greater efficiencies in the technology and therefore lower cost this may be a worthwhile investment.

In summary, the UK is showing great effort in pursuing the technology with the intent to deploy at a commercial level. It is only when at this level will the true risk be identified and analysed in order to determine its success.

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