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Can Government policy make the difference?: Analysis of the Long and Short-term prospects for Government Economic Policies to commercialise Carbon Capture and Storage, Biomass and reduced CO_2 transport technologies in the UK

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Abstract

The article analyses the capability of carbon abatement technologies to be made commercially viable by way of government policy incentives over a long and short-term time frame. It is concluded that Carbon Capture and Storage (CCS) and Biomass require issues such as technological improvements and infrastructure scale up to be resolved positively to realise their long and short-term potential. Low CO_2 transport meanwhile is highly dependent on the construction of infrastructure which commercial success with the other two technologies would instigate. Broader implications are also drawn by reference to the UK's advantages and disadvantages in the Global market. These reveal that the UK has strong opposition from foreign businesses in bio-fuels and low CO_2transport but can potentially perform CCS more economically due to its geographic location. The study draws on an interview conducted on 25thMarch with Dr. Peter Iron. Dr. Iron's career started in the UK where he worked for British coal researching clean coal technologies. After obtaining his PhD in Chemical Engineering at Imperial College he then moved to Australia to work as a senior research manager for CSIRO's (Commonwealth Scientific and Industrial Research Organisation) Low Emission Technology Centre in Brisbane Australia.

Introduction

The effects of climate change are now a truly global issue requiring a global response (Stern, 2007) and developed countries like the UK are at the forefront of pioneering strategies and technologies aimed at reducing the carbon content which our economic activities implicate (Roeser and Jackson, 2002; DTI, 2007). In meeting such challenges governments have come to assume a leading role; as the then chancellor Gordon Brown stated "In the 20thCentury our National economic ambitions were the twin objectives of achieving stable economic growth and full employment. Now In the 21stcentury our new objectives are clear, they are threefold: growth, full employment and environmental care" (White, 2007, p.150). Subsequently the government passed the 2008 Climate Change Act setting near-term goals of reducing carbon emissions by 26% by 2020 and 80% for the long term date of 2050 (OPSI, 2008). Similarly in this study where something is referred to as short or near-term it should be taken to mean 2020 and long-term 2050.

Technology and government policy are often seen as key drivers in the commercial scale adoption of such technologies (Stern, 2007; White, 2007; Dunn, 2002; Cogan, 2007; DTI, 2007a; Roeser and Jackson, 2002). This broad consensus is reflected here by analysing the potential interaction between crucial government policy tools like the Carbon Reduction Commitment (CRC) with technologies recognised for their high CO_2abatement potential (Stern, 2007; DTI, 2007a).

By firstly evaluating the financial incentive provided by the CRC it is intended that this will provide a preferable position from which to judge the commercial viability of Carbon Capture and Storage (CCS), Biomass and reduced CO_2transport technology. Furthermore by considering factors related to global geographic variables it is hoped that some of the broader implications of the research may be discerned such as any strengths and weaknesses that UK business's possess relative to foreign companies wishing to make profits through application of the same technologies.

This study therefore presents:

- An evaluation of the potential for UK government policy incentives to make CCS, Biomass and reduced CO_2 transport economical for UK businesses
- An account of potentially crucial global geographical influences which may inhibit or enable successful technology transfer in these areas to generate profits for UK business's

The Carbon Reduction Commitments Cap-and-Trade Scheme

The CRC incorporates a new form of Cap-and-trade Scheme whereby large corporations must assess their legal obligation to join the scheme on the basis of whether their total yearly electricity bills in 2008 are over 6, 000MWh through half-hourly metering (CRC Magazine, 2009; Langridge *et al*, 2008; DEFRA, 2008). If so they fall within the scheme and are obliged to make records accounting for all their core energy usage, meaning the inclusion of all electricity, gas and oil consumption except for transport (Ibid).

Companies eligible for the scheme will also be entered into the CRC league table where their yearly CO_2 reduction performance will be ranked on the basis of three measurements expounded in figure 1 (ibid). It is after April 2011 that the first Carbon allowances will be sold prior to the auctioning phase to companies on the basis of actual emissions for 2010/11 and what the company expects to emit in 2011/12 (Ibid). In 2013 the first capped 5 year phase begins where prices for allowances will no longer be fixed but must be bid for in an auction (Ibid). However this is not compulsory as companies may use a buy only safety valve (Langridge *et al*, 2008) option where allowances are bought from other schemes like the EU Emissions Trading Scheme (ETS) if the highly competitive nature of the auction system were to drive prices too high (Langridge *et al*, 2008; CRC Magazine, 2009).

Metric	**Method for Obtaining Metric**	**1st year of incorporation into CRC League table**	**Reason for Incorporation into CRC League table**
Early	By enumerating the value of actions taken by a company to decrease CO_2 emissions before April 2011	01/04/10 - 01/04/11	To reward early action
Core absolute reduction	compares the companies carbon emissions reduction for that year against a rolling average for their previous years under the scheme building up to 5 years by 2013 which will be maintained	01/04/11 onwards	To provide an effective means of measuring CO_2 reduction performance over a short-term time frame

	thereafter		
Growth	Same as absolute reduction method except that it obtains its value from the percentage reduction of CO_2 emissions per unit of turnover or if a measurable indicator of production cannot be found per unit of revenue	01/04/11 onwards	in order to consider the relative efficiency in Carbon reductions when company growth is taken into account

Figure 1: Measurement values used to compile the CRC League table, the time frame for their implementation and policy reasoning behind their use (source: author, adapted from Langridge *et al*, 2008; DEFRA, 2008; CRC Magazine, 2009)

There is considerable consensus that Cap-and-trade schemes like the CRC are essential in increasing the potential business opportunities in Low Carbon technology as they provide an added financial incentive for companies to develop them (DTI, 2007; MIT, 2008; Stern, 2007). Indeed, Singleton's (2007) assertion that billions are already traded every year under such schemes would appear to support this argument. However their effectiveness in meeting these ends has been questioned on a number of grounds.

These stem from Stern's (2007) concern that companies must have faith in the new policies and the legal framework which backs it up or else they may not account for the price of carbon in their business strategies; potentially leading to excessive investment in long-term, carbon intensive infrastructure consequently leaving carbon management issues to escalate later on. On the other hand as Dunn (2002) recognises a mandatory scheme arguably offsets some of these issues as it decreases some of the problems encountered due to the fragmentary fashion in which ETSs have developed in the past (Dunn, 2002; Roeser and Jackson, 2002). However certain issues may test company faith in the scheme.

First resolving particular definitional issues like 'half-hourly metering' (Langridge *et al*, 2008, p.19) are of paramount importance if the legal framework is to be trustworthy. Furthermore the early metric while a useful further incentive for rapid action is problematic because it is only semi-objective in the way it assesses the value of early actions due to using the more objective electrical meter recordings along with their coverage and rating under the Carbon Trust standard (CRC Magazine, 2009; The Carbon Trust, 2009a; Langridge *et al*, 2008). The latter includes highly subjective criteria such as a company's ability to 'demonstrate good carbon management' (The Carbon Trust, 2009a, p.1). It is arguable therefore, especially in such a maturing field that companies will feel unsure of their ability to meet such standards.

The growth metric is also problematic as it is less environmentally sound because using units of production does not allow CO2 reduction to be measured through definite indicators, making their auditing and verification troublesome (Roeser and Jackson, 2002; CRC Magazine, 2009; DEFRA, 2008; Langridge *et al*, 2008). These problem may be reduced though with the employment of independent third party auditors (Zarsky, 2002) like the accounting firm Price Waterhouse Coopers (2009) who might be able to give a more objective assessment of these values and the fact that the growth metric is not the only measurement. So while the CRC has a great deal of potential in the long-term there are well founded reasons to believe it's anticipated ability to deliver business opportunities and nationwide carbon cuts in the short-term may not succeed until these issues have been resolved.

Having identified generally some of the key issues involved in assessing the degree of business potential of the CRC for CO_2 mitigation the study will progress to how it may interact with the following Carbon reduction technologies to either hinder or encourage Low Carbon business opportunities.

Carbon Capture and Storage

CCS (Carbon Capture and Storage) has the potential to account for 28% of global CO_2abatement by 2050 (DTI, 2007a; Stern, 2007). Capable of being applied to both coal or gas fired power generation, it offers by far the largest potential for CO_2 abatement (see figure 2 showing that public power and heat production is the largest global source of CO_2) especially when we consider that carbon capture and storage has the prospect of decreasing CO_2emissions from fossil fuel power stations by up to 90% (DTI, 2007a). This potential was acknowledged by the European council when it stated near-term goals of ensuring all post-2020 fossil fuel power generation plants have CCS capabilities if the process is economically viable (DTI, 2007a).

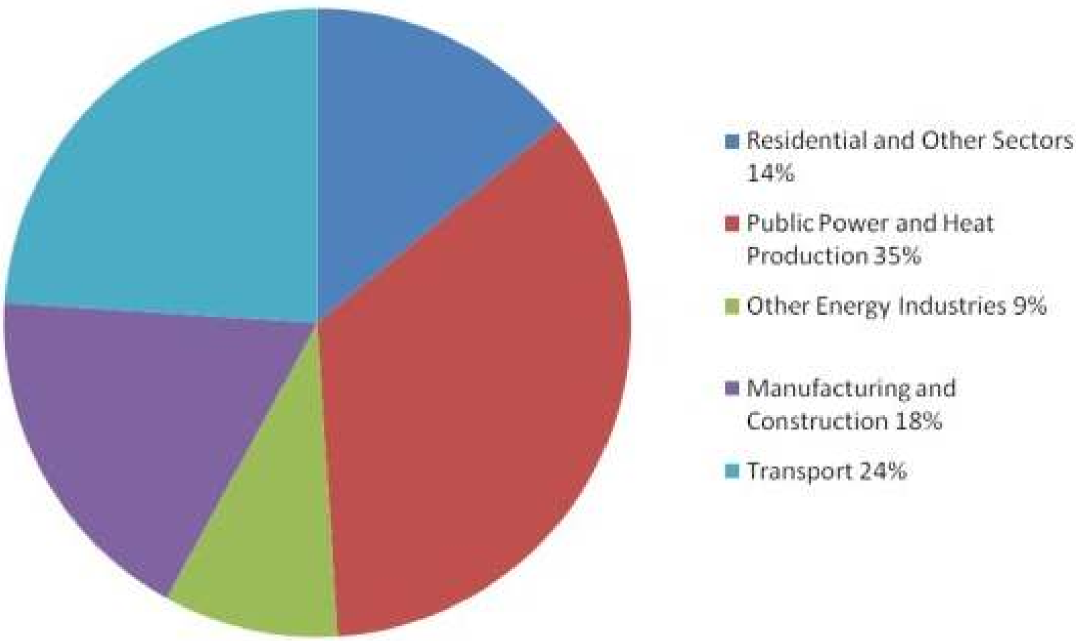

Figure 2: Global CO_2 sources from energy use (adapted from IEA (International Energy Agency), 2005)

The Capture options with greatest potential for success are known as Post-

Combustion[1], pre-combustion[2] and oxy-fuel capture[3] (DTI, 2007a; Iron, 2009a, Interview; IEA, 2005; MIT, 2008). Post-combustion involves using powerful chemical scrubbers to capture CO_2 from flue gases[4] while oxy-fuel involves combusting the fuel in oxygen with recycled flue gas then compressing it at low temperature to capture pure[5]CO_2 (Iron, 2009a, Interview; IEA, 2005). Pre-combustion uses the gasification[6] (Iron, 2009a, Interview) process 'to react the fuel with oxygen under pressure'[7] (Iron, 2009a, Interview, p.3) producing a fuel gas[8] (Iron, 2009a, Interview). A pre-conditioning process using steam and a catalyst is used to convert Carbon Monoxide in the resulting fuel gas into Hydrogen and Carbon Dioxide which is subsequently captured with a chemical scrubber[9] (Iron, 2009a, Interview).

The transport system to deliver CO_2 to storage sites will most likely involve a network of pipelines leading to geological sinks where it will be trapped[10] (Poyry, 2007; Iron, 2009a, Interview). The main types of geological formations which are capable of trapping CO_2 long-term are, firstly, depleted oil and gas fields which will be trapped under the impermeable cap rock[11] (Ibid). Secondly, formations of porous sandstone holding brackish water known as saline aquifers which will trap liquid CO_2 injected into these pores[12] (Iron, 2009a, Interview; Poyry, 2007; Scottish Centre for Carbon Storage, 2009). Lastly coal seams which have been extracted of methane for natural gas but are otherwise uneconomical for mining providing extensive space for further storage[13] (Iron, 2009a, Interview).
However in spite of this great potential for reducing CO_2 emissions economising the technology is the biggest issue both for its long and near-term prospects and will depend on a number of factors. Some of the most commonly cited are(DTI, 2007; Iron, 2009a, Interview; Poyry, 2007; MIT, 2008):

1. Establishing a secure legal framework to legitimise the process and provide economic policies such as cap-and-trade schemes to give financial incentives to companies thus increasing economic viability[14] (Poyry, 2007; Roeser and Jackson, 2002; DTI, 2007a; Iron, 2009a, Interview; MIT, 2008)

2. The projected future prices of electricity, fuel and CO_2 (Poyry, 2007; Roeser and Jackson, 2002; DTI, 2007a; MIT, 2008)

3. The availability of other CO_2 abatement technologies such as Nuclear, renewable power and different techniques of Capture, transport and Storage (DTI, 2007a; Poyry, 2007)

4. Scaling up the pilot demonstrations of CCS to a commercial scale level for power production, thereby realising cost reductions due to economies of scale (Stern, 2007; DTI, 2007a; Poyry, 2007; IEA, 2005; MIT, 2008)

5. Developments in technology which may reduce the cost of CCS, especially capture costs[15] (MIT, 2008; Iron, 2009a, Interview; Stern, 2007)

Of these issues, the first is arguably developing most positively towards improving the near-term business prospects of CCS (MIT, 2008; DTI, 2007a; BBC, 2009). This is evident by the Climate Change Act 2008 having established mandatory cap-and-trade schemes and amendments to global marine environmental law such as the 1996 protocol to the London and OSPAR conventions to allow CCS to be recognised as a carbon abatement option and to legalise the storage of CO_2 in geological formations (MIT, 2008; CRC Magazine, 2009; DEFRA, 2007; Langridge et al, 2008; OPSI, 2008). Furthermore the government recently agreed to distribute funds of £4 billion to energy companies planning four pilot CCS plants under its CCS demonstration competition (DTI, 2007a; BBC, 2009). Therefore while there is work still to be done, these developments have made significant progress towards speeding up the process of economising CCS.

The future price of electricity, carbon and other raw materials is already threatening the prospects for commercial scale CCS due to global recession with the cost of capture going up 10-20% relative to 5 years ago due to increasing raw material costs (MIT, 2008; Gibbens and Barnett, 2008). Furthermore it is not clear that carbon prices will be sufficiently high to make it economical as even with Carbon prices at £5/tonne CO_2 profitability for CCS here is only likely to begin at £25/tonne CO_2 (Poyry, 2007; Roeser and Jackson, 2002). However, it must be considered that there is a good chance of this changing long-term as the social costs of carbon increase (Stern, 2007). Whether or not we accept this we must also acknowledge the short-term prospect of the portfolio of options available for transport, storage and capture technologies to reduce costs as it gives power producers the opportunity to select methods of CCS which are most economical to the circumstances of their power plant (MIT, 2008).

On the other hand, such a range of technologies untested at commercial power plant scale and of such varying cost can cause uncertainty for the investor thus making the financial risk to the investor insurmountable (Stern, 2007; DTI, 2007a; Poyry, 2007; IEA, 2005; MIT, 2008). Indeed as Stern (2007) would argue scaling up is the key to commercial success, as this allows the realisation of economies of scale due to the sheer volume of CO_2 needing to be captured, stored and transported (Poyry, 2007; Stern, 2007; DTI, 2007a). Therefore, while scale up must be achieved to obtain CCS's full carbon reducing potential, this gap cannot be bridged easily.

DTI's (2007a) competition for demonstration of CCS may help increase investor confidence in the technology, however, this does not change the fact that the cost of capture is in many cases far in excess of near-term economic feasibility (Poyry, 2007; MIT, 2008; BBC, 2009; DTI, 2007a). By contrast it may be argued that the long-term prospects are far better especially when the potential for developments in technology to reduce the cost of Capture are considered. Not only are advanced solvents and oxygen membranes promising to produce significant cost cuts for post-combustion and oxy-fuel capture but developments in pre-combustion capture are promising to play a huge part in decarbonising transport, residential and industrial power demands. This is because pre-combustion capture has economic advantages due to the hydrogen produced[16] (Iron, 2009a, Interview; IEA, 2005). Therefore a hydrogen pipeline network could provide transit to a fuel with the capacity to power all major forms of transport if hydrogen fuel cells were widespread[17] (IEA, 2005; Iron, 2009a, Interview). In light of this then it is surely not too far fetched to suggest that while CCS is not yet fully commercially mature it could be a huge growth market long-term.

Biomass

Biomass is a term for any organic material sourced from plant matter[18] (Iron, 2009b, Interview). As well as producing less CO_2 than fossil fuels when combusted for energy it is also renewable which requires plants capturing CO_2 thereby further reducing the amount in the atmosphere (E.on, 2009; DTI, 2007a; DTI, 2007b). Biomass has a range of applications from various types of fuels for transport[19] to electricity generation (DTI, 2007a; DTI, 2007b; MIT, 2008; Iron, 2009b, Interview). These two broad areas however offer the biggest potential reduction in CO_2 emissions as is reflected, especially with the former by the establishment of policy incentives and publicly available documents designed to increase commercial feasibility via financial incentives and clear strategic guidance for businesses considering investing in these technologies (DTI, 2007a; DTI, 2007b; CRC Magazine, 2009; DEFRA, 2007; Langridge *et al*, 2008). These include:

- The Carbon Reduction Commitment which specifically recognises the potential of Biomass technology for CO_2 abatement (CRC Magazine, 2009; DEFRA, 2007);

- Publishing the 2007 Energy White paper (DTI, 2007a) and UK Biomass Strategy (DTI, 2007b) outlining planned policy incentives (DTI, 2007a) and the present and projected market penetration of near and long-term commercially viable bio-fuels (DTI, 2007b) based on:

- Present and projected supply and demand of bio-fuels (DTI, 2007b)

- The present and projected availability of other CO_2 abatement options (DTI, 2007a; DTI, 2007b)

- The business prospects for substantially cheaper 'second generation' (DTI, 2007b, p.50) bio-fuels

- The anticipated effect of policy incentives (DTI, 2007a; DTI, 2007b);

- The Renewables obligation which sets targets for the UK to increase the percentage of electricity produced through renewables in yearly steps from 6.7% in 2006/07 to 15.4% by 2015 (DTI, 2007a; DTI, 2007b; E.on, 2009). Towards achieving this end it provides support to companies using methods of power generation utilising renewable fuels such as the co-firing of Biomass with fossil fuels (MIT, 2008; DTI, 2007a; DTI, 2007b);
- The RTFO (Renewable Transport Fuel Obligation) (DTI, 2007a; DTI, 2007b) requiring oil companies to ensure 5% of transport fuel sales come from renewable sources by 2010/11 (DTI, 2007a; DTI, 2007b).

Such policies have already shown promise of providing a near-term market share for Biomass in electricity generation (DTI, 2007a; DTI, 2007b), particularly for Biomass and fossil fuel co-firing plants where the cost-effectiveness of such a method has already been demonstrated at a commercial scale due to financial assistance under the Renewables obligation[20] (DTI, 2007a; New Energy Focus, 2009; Iron, 2009b, Interview). Hence the forthcoming CRC should increase profitability still further as it provides up to a 10% reduction in CO_2 over conventional combustion methods and previous experience suggests that further commercial scale up should also decrease costs (Stern, 2007; DTI, 2007a; DTI, 2007b; Yeoh, 2007; CRC Magazine, 2009; DEFRA, 2007; Langridge *et al*, 2008).

On the other hand prospects for the sole combustion of Biomass in commercial power stations are much less promising. The process suffers economically mainly due to the lower heating value relative to fossil fuels which increases the cost of power generation and resulting cost of transporting the Biomass as more fuel is needed to produce the same amount of energy as fossil fuels[21] (Iron, 2009a, Interview; DTI, 2007b). The CRC would also, appear to be far from adequate to economise the process as would most other financial support, like the Renewables obligation which DTI (2007b) agues is far too expensive for the scheme. The government therefore seemingly favours co-firing options, at least for the short-term making commercial scale dedicated Biomass power generation seem unlikely at best (DTI, 2007a; DTI, 2007b).

Bio-fuels for transport have uncertain business prospects. While the global market has shown positive trends recently current Bio-fuels arguably look too expensive in the UK to expand beyond the mandatory 5% share of the transport fuel market the government has imposed for 2010/11 there is an equally strong consensus that the second generation Bio-fuel technology currently being developed has the capacity to significantly cheapen the fuels (DTI, 2007b; Stern, 2007; DTI, 2007a; Makower *et al*, 2007). Despite the fact that government policy incentives such as the Low Carbon Transport Innovation Strategy are offering £20 million to assist UK research into such technologies, however doubt still remains on the pace of forthcoming developments and the exact degree of cost reduction they could offer (DTI, 2007b; DIUS, 2007; DTI, 2007a). Hence there are significant financial risks in investing in the technology especially in the short-term in light of recent global recession (Gibbins and Barnett, 2008; RFA, 2008).

Companies will be still further discouraged from investing due to the fact that they do not have to record transport fuels under the CRC (Langridge *et al*, 2008; DEFRA, 2007; CRC Magazine, 2009). Still though it is worth bearing in mind that if oil prices were to rise due to insecurity of supplies that 'the economics become more favourable'[22] (Iron, 2009b, Interview, p.5; Gibbins and Barnett). If the very real long-term possibility for this scenario is combined with the commercial use of advanced cost-saving technologies, then they may have a far greater share of the commercial fuel market than the enforced 5% minimum. If the CRC were altered later to require companies to include transport fuels in their records which, if Stern's (2007) argument regarding the ever increasing social cost of Carbon over time is accepted would also seem a long-term reality the profit making potential increases still further.

Low Carbon Transport

Transport represents about one quarter of UK domestic CO_2 emissions and so represents a potentially huge market area for technologies able to offer cost-effective carbon abatement technologies (DTI, 2007a). Indeed, this potential is already being recognised and exploited (see figure 3 which shows the high sales figures for the top sellers of low CO_2 transport). It should be borne in mind though, as figure 3 demonstrates that none of the current market leaders in this area are British companies, showing that while many of the technological improvements listed in figure 6 may produce significant CO_2 reductions from the existing carbon footprint which are economic activities implicate, it is not UK Businesses capitalising the most on them.

Company	Sales in 2005 (Dollars)	Market area
Honda	80, 872, 000, 000	Through selling hybrid(Powered by an electric engine in tandem with a conventional fossil fuel combustion engine (White, 2007; Cogan, 2007)) vehicles and low emission diesel passenger cars
Nissan	80, 182, 000, 000	By selling hybrid and alternatively fuelled passenger and commercial vehicles
Peugeot	66, 371, 000, 000	By using efficient diesel engines, compressed natural gas and ethanol
Chevron	184, 922, 000, 000	By producing state of the art battery systems for use on electric and hybrid vehicles
Toyota	173, 444, 000, 000	Through the sale of hybrid cars

Figure 3: Sales of the market leaders in low CO_2 transport in 2005 (adapted from White, 2007, p.153)

Government economists are distributing funds of £20 million for UK research into low carbon transport technologies to change this which could go to market in the next 5-7 years under its Low Carbon Transport Innovation Strategy (DIUS, 2007; DTI, 2007a; DTI, 2007b). Furthermore the RTFO should further incentivise the economics of Low Carbon Transport options, particularly Bio-fuel cars, especially if the Government opts to increase it although success in this area is tied to the highly uncertain business potential of Bio-fuels described earlier (DTI, 2007b; DTI, 2007a). However it is difficult to see how the mandatory 5% blend of Bio-fuels may increase in the short-term as it is uncertain whether percentages higher than this might cause mechanical faults in older cars (DTI, 2007a). This highlights that such technologies can still be substantially economised by further scale up, therefore possibly restricting their short-term potential (Stern, 2007; DTI, 2007a).

On the other hand a raft of other policy incentives should speed up the purchase of newer, low Carbon vehicles:

- Changes to vehicle excise duty and company car tax in 2001 and 2002 respectively so that the scale of excise or tax increased with CO_2 emissions (DTI, 2007a)
- Increasing fuel duty in steps of 2p/litre in 2007 and 2008 followed by 1.84p/litre in 2009 (DTI, 2007a)
- A 35p/litre incentive to use bio-fuels due to the combined effect of a fuel duty differential and the RTFO (DTI, 2007a)
- Replacement of older vehicles for £2,000 (The Times, 2009)

Therefore while the decision not to oblige companies under the CRC to record transport fuel uses might be regarded as a missed opportunity to incite further capital gains in this emerging technology it is clear that the economics are and may become more favourable in the near-term (Langridge *et al*, 2008; DEFRA, 2007; CRC Magazine, 2009).

Looking Longer-term the potential to move away from current market performers like hybrid cars [1] to completely carbon neutral technologies is dependent on the successful commercial scale implementation of a number of key components in a decarbonised economic infrastructure (White, 2007; Cogan, 2007). Most notably in the UK context, this refers to the success of technologies like pre-combustion capture CCS discussed earlier which could provide completely CO_2 neutral transport when other key components, such as hydrogen pipe lines and hydrogen fuel cell powered transport are also widespread (Iron, 2009b, Interview). However the problems outlined earlier regarding bio-fuels in older cars show how long it can take the economy to adapt to even small changes as well as the reality that, in the short-term at least many other low carbon transport technologies may be explored, meaning if and when the government decides it wishes to go down this path it will take longer to realise significant economies of scale.

Conclusion

In Conclusion Carbon Capture and Storage's short term potential is limited due to the financial risk for would be investors due to the rising cost of materials and in scaling up the infrastructure necessary to economise the process. Cap-and-trade schemes are insufficient to offset these costs. Long-term prospects are better due to the potential for technological improvements to reduce costs, government assisted construction of pilot scale plants and the likelihood of the social cost of CO_2 increasing over time (MIT, 2008; Iron, 2009a; IEA, 2005; BBC, 2009). The UK benefits geographically from numerous close and economical sinks located in the North Sea (Poyry, 2007; MIT, 2008). This should decrease the cost of transport and storage.

Co-firing of Biomass with fossil-fuels in power stations is economically viable now due to assistance under the renewable obligation and CRC. Sole firing of Biomass however is costly due to the lower energy content of the fuel even with the implementation of the CRC (DTI, 2007b; Iron, 2009b, Interview). The long-term prospects of this improving are still not promising for the same reasons. However we should not rule out the capacity for technological improvements and the increasing social cost of carbon to economise it (Stern, 2007). In the near-term the prospects for transport bio-fuels are reasonable due to the policy incentives outlined. However such fuels will still struggle to compete with cheaper fossil fuels. Looking long-term the economics look more uncertain but the potential for technological improvements and the anticipated rising social cost of CO_2 and potentially depleted global fossil fuel may economise it. Another problem from a global perspective is that it is substantially cheaper to import Biomass from places like Brazil where greater space for farming results in less competition for uses of arable lands (DTI, 2007b). Therefore the UK's agricultural sector may struggle to make profits from such crops.

The prospects for reduced CO_2 transport for British businesses might be somewhat doubtful in the near-term because foreign car manufacturers are coming to dominate the market. The high cost of producing bio-fuels in the UK (DTI, 2007b) only serves to compound the problem. But while the market leaders are not British the government's policy incentives could offer some hope in stimulating investment in this area (DIUS, 2007; DTI, 2007b) although this is unlikely to occur unless the infrastructure change required to economise the process occurs simultaneously. Because this will take time the long-term prospects are much better if these changes begin now, especially for bio-fuelled and hydrogen fuelled vehicles. In the case of hydrogen-fuelled vehicles the wide-scale use of pre-combustion CCS could prove particularly crucial in providing a cheap source of hydrogen.

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Appendix

Iron, 2009a: Relevant excerpts from the transcript of the Interview on Carbon Capture and Storage

Interviewer-Please explain briefly the process of Carbon Capture and Storage.-

Respondent- The three capture options with the greatest probability of success are:

A. Post Combustion Capture (PCC)[1] is the technology that could be most quickly implemented at existing combustion power plants. A carbon dioxide scrubber would be installed before the flue; the scrubber needs to use a strong chemical solvent to capture the gas from the flue gases[4], as current power stations burn their fuel in air (20% oxygen, 80% nitrogen) and this causes the concentration to be reduced by large amounts of nitrogen. These solvents then need to be regenerated for re-use, and because they are strong solvents the regeneration process is energy intensive. Although the technology is commercially available for other applications, it has yet to be demonstrated at the scale of power production and incurs both a substantial loss in efficiency and an increase in cost relative to current power production without capture; there are also technical issues to be resolved in ensuring that the solvent life is adequate to be economically viable, and that solvent losses from the process do not constitute an emission problem in themselves. PCC technology is the subject of an existing UK government call for demonstration proposals in the UK, 4 pilot projects in Australia and a number of other projects worldwide

B. Pre-combustion capture[2] uses a process known as gasification[6] to react the fuel with oxygen under pressure[7]to make a combustible fuel gas[8]; this avoids dilution of the gas with nitrogen, reducing the cost of capture. A preconditioning process uses steam and a catalyst to convert the carbon monoxide in the raw fuel gas from the gasifier into carbon dioxide and hydrogen[9], a chemical reaction known as the "water gas shift". The capture is then done by scrubbing the fuel gas, but because the carbon dioxide is more concentrated and under pressure the scrubber may use a weaker physical solvent that is less energy intensive to regenerate. The maturity of the technology for capture is similar to that of PCC, but power production by gasification is not widespread or as reliable as combustion. However pre-combustion capture has the unique advantage of being able to co-produce a valuable decarbonised fuel (hydrogen)[16] that could be used to decarbonise transport and assist in following power market load changes[17] . Oxyfuel[3] combustion burns the fuel in oxygen diluted by recycled flue gas, thereby avoiding dilution of the flue gas with nitrogen from the air. The carbon dioxide is then captured by compressing the flue gas and cryogenic (low temperature) separation from the impurities[5]. This technology does not co-produce hydrogen but appeals to power generators because of the similarity to conventional combustion plant.

Geosequestration is common to the application of all these capture options, and here the main issues are security, location, capacity and economic viability. A formation is potentially suitable if it is capable of preventing release of the carbon dioxide for many centuries[10]; areas of current volcanic or earthquake activity are unlikely to be suitable. The formations that are most likely to meet this requirement are:

C. Depleted oil and gas reservoirs, which having previously stored oil or gas for very long periods will have the necessary impermeable cap rock[11] and geometry to store carbon dioxide. Oil production from old oil wells is commonly enhanced by the injection of carbon dioxide, and permanent retention may be possible after production of oil has ceased from the same oil wells. The enhanced oil production may provide some initial revenue, potentially improving the business case for the project. However the location of exploration wells in the oldest oilfields (e.g.Texas) is frequently not well recorded, presenting the possibility of the formation leaking. Some of the best documented prospects for this type of storage are situated in the North Sea, if the timing of storage implementation can be aligned with the timing of oil production infrastructure becoming redundant. Saline aquifers are deep bodies of porous sandstone containing brackish water that is unsuitable for supplying water for other purposes. Carbon dioxide may be injected into these and trapped as a liquid in the pore space, dissolved in the water to form bicarbonates and (after a long time) form solid minerals[12].

D. Coal seams often contain enough methane to be attractive sources of natural gas, but may be too deep, too low in quality or otherwise unsuitable for mining. Coal is able to store a greater quantity of carbon dioxide than methane, making these deep unmineable coal seams potential storage opportunities after the methane has been removed[13].

Interviewer- What factors threaten the commercial scale application of these technologies?

Respondent- It will always be cheaper to emit carbon dioxide from a power station to the atmosphere than to capture it, unless emissions are penalised. A tax or penalty on emissions is therefore essential for implementing CCS, and an emission trading scheme (ETS)[13] is one way of applying the required penalty with the aim of minimising the overall cost to the consumer.

Interviewer-What factors can make them economically viable?

Respondent- An internationally-agreed and enforceable penalty for carbon dioxide emissions (such as an ETS scheme) and inter-governmental financial support specifically for demonstration plants[14].

Interviewer-What do you feel the short (i.e. 2020) and long-term (i.e. 2050) prospects are for commercial scale implementation of these technologies?

Respondent- The following schedule should be achievable, but only if the measures outlined under 3) above are expedited, a "wartime" approach without concern for IP ownership is adopted and there are no major unforeseen events (wars, plagues, etc):

- By 2020 the current options will have been demonstrated and ready for decisions to be made on commercial scale implementation. A number of cost reducing improvements will be ready for demonstration in 2ndgeneration plants[15].

- By 2050 there will be widespread commercial implementation of CCS at substantially lower cost, the market penetration achieved by the technology depending upon competition in the power market with renewable and nuclear power.

Iron, 2009b: Relevant excerpts from the transcript of the Interview on Biomass Technologies

Interviewer- What are the potential uses of Biomass?

Respondent- Current liquid bio-fuels for transport[19] use are usually derived from purpose-grown crops, there is therefore an immediate clash with the demand for land to grow food; also bio-fuel production from the crop may have a similar or worse carbon emission signature than oil refining, so that when you add in the carbon signature of the fossil-energy derived fertiliser and fuel used in harvesting their impact may be worse than simply using oil as your source of transport fuel regardless!

Biomass is distinguished by being a waste material for which there is no (or limited)

other use; a good example would be Bagasse, the stalks left over from sugar cane after the sugar has been extracted. In common with many biomass materials it is largely cellulose[18].
Bagasse is also a potential source of energy as heat[19], it has been burnt for decades to raise steam to run sugar mills in the sugar belt. The boilers at the sugar mills are low efficiency, they don't have to be any better when the fuel is essentially free, and don't export energy as steam as there is no demand for steam locally outside the sugar mill and it can't be transported long distances. The boilers are also not large enough to generate electricity at a price that could compete with large standalone power plants running on coal or gas. There is a huge excess of Bagasse over the energy needs of the sugar mills, so material furthest from the mill is simply burnt in the fields.

Interviewer- So it is reasonable to ask whether a Biomass like Bagasse could be used to produce electricity in a larger plant?

Respondent- A larger plant could be designed for higher efficiency, but to compete with coal or gas -only firing the plant would then be mismatched to the availability of Bagasse; the fuel has a low heating value (particularly when expressed on a density basis, i.e. it's light) relative to gas or coal so the source needs to be within say 50km of the power plant for the logistics, transport cost and the associated carbon emission to be acceptable[21].

A technically viable method of using biomass that suits some other biomasses like olive Pitt or palm nut waste is to blend it with coal and burn it in an existing power plant. Generally 10% or less substitution is acceptable without harming the operation of the power plant. But this is only economically attractive if the power from such a plant is going to get a higher price. Some power producers in the UK have been exploiting this to meet the market's obligations to generate power from non-fossil sources[20]; it's cheaper and quicker to do this at an existing coal-fired power plant that will run at >85% capacity than to get planning permission for an expensive new wind turbine which will only produce about 30% of it's rated capacity (because of periods of too low or too high wind speed). But you have to ask whether the cost of carbon emission for transporting palm nut waste from the other side of the world to the UK have been counted.

Interviewer- So what factors can make Biomass technologies economically viable?

Respondent- Well, most of what I've said relates to the use of biomass to make electricity; but if you can use it to make another, more valuable product to substitute for oil as a liquid transport fuel or a chemical the economics may become favourable[22] if oil supply security or price become issues again. Gasification is the technology that can be used to do this; using either coal or a coal/biomass blend as the feed, the blended feed could potentially produce liquid transport fuels with a lower (full LCA) carbon emission than oil, as the biomass "offsets" the carbon signature. However gasification of natural gas is cheaper and likely to use less water than either coal or coal/biomass!