CARBON CAPTURE AND STORAGE
BURY THE MYTH AND FOCUS ON ALTERNATIVES

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In theory, carbon capture and storage (CCS) mitigates the effects of climate change by pumping carbon dioxide underground. It proposes to reduce emissions without curbing the use of fossil fuels and, as a result, has been advocated by energy corporations, governments and international institutions. Much academic research also favours the idea. Criticism is often isolated and purely technical. However, surveys indicate that the public is either ambivalent towards CCS or has reservations about its use.

The public is right to be cautious: CCS is expensive, high risk, and may actually increase emissions due to greater demand for coal. These technical drawbacks alone suggest that the government's commitment to CCS does not add up. Cheaper and more reliable options exist, yet these rarely enter the debate. To overcome this, the concept of an 'energy hierarchy' can be used to highlight the full range of options for meeting climate change and energy security commitments. Criticism of CCS can therefore be seen as an opportunity to re-evaluate energy policy priorities and focus on the proven and economically prudent measures of energy conservation and efficiency.

Introduction

Carbon capture and storage is not, as its name suggests, a single technology. It can be defined as the separation, transportation, and sequestration of CO_2 arising from burning fossil fuels. CCS is complex and requires expensive technologies, many of which come from the oil industry (figure 1).

In political debate the idea is grossly oversimplified. When he was secretary of state for energy and climate change, Chris Huhne frequently referred to CCS as a 'key technology' that was 'essential', yet showed little understanding of the many technologies involved.[1] This simplistic view seems to be shared: in the Hansard records 53 MPs have mentioned 'CCS technology' during recorded parliamentary debates yet only one, from Scotland, has referred to the underlying science.[2] If the technical risks are not understood, an overly optimistic assessment of CCS may be the result (Hansson 2009). Lack of scientific knowledge about CCS, such as the impacts on plant

1 Hansard, Parliamentary answers to Malcolm Wicks, Annual Energy Statement, HC Deb, 23 November 2011, c305. Term tracked at http://www.theyworkforyou.com

2 Patrick Harvey quoted Ehlig-Economides and Economides (2010) to cast doubt on the capacity of pore spaces in rock to sequester CO_2 on the scale required. Hansard, Climate Change debate, Scottish Parliament, 18 March 2010, http://www.theyworkforyou.com/sp/?gid=2010-03-18.24710.3

efficiency and thereby rates of coal depletion, hinders informed debate on the subject. These things matter because they can result in the promotion of a technology that may not live up to its promise.

Figure 1: Key phases, processes and corresponding technologies in the CCS supply chain

Phase	Separate CO_2	Transport	Sequestration	Site management
Processes[a]	Post combustion[b]	Compress waste gases[d]	Drilling	Above-ground site monitoring
	Pre-combustion	Pipeline construction[e]	Injection[f]	Below-ground site monitoring
	Oxyfuel combustion[c]	Pipeline operation		
	Amine-based solvents	Large compressors	Oil and gas drilling and enhanced oil recovery (EOR) technologies	3d seismic, time-lapse gravity, and satellite survey techniques
	Integrated gasification combined cycle (IGCC)	Steel pipelines[g] and fans from oil and gas industry	High chrome steel pipes[h]	Vertical seismic profiling, flow meters[i]

Notes: a) Forbes et al (2008); b) Wall (2007); c) Buhre et al (2005); d) compression energy costs are large, ~100 kWh/TCO_2 using a 31 MW centrifugal compressor (Koornneef et al 2008); e) pipelines were estimated to cost $18m to $102m per 100 km in China (Liu and Gallagher 2011); f) Michael et al (2010); g) Liu and Gallagher (2011); h) Pfennig and Kranzmann (2009); i) Michael et al (2010)

The public appears to be less optimistic than politicians: opinion polls indicate that attitudes toward CCS are largely ambivalent or mildly opposed.[3] Overall CCS has a low public profile.[4] This, together with the lack of scientific understanding amongst politicians, makes it timely to present the case against CCS in a straightforward and succinct way.

The case against CCS

In a nutshell, CCS is expensive, risky, and may not reduce global greenhouse gas emissions. Even assuming minimal CO_2 leakage, the wider impacts include risk-laden and energy-intensive infrastructure and increased methane emissions. These issues are rarely stated in political debate.

These arguments are not widespread because existing criticisms of CCS often focus solely on one technological problem or legal difficulty. Few have confronted the idea directly and comprehensively[5] whilst providing viable alternatives. The condensed argument presented

3 See Tyndale Centre (2009): 'On first contact with the idea ... most people (48 ±7per cent) are neither for nor against›. And a large amount (38 ±6.5 per cent) expressed ‹slight or strong reservations›.

4 An international study found 'low levels of awareness, recognition or understanding of CCS' (Reiner et al 2005).

5 A notable exception is 'Carbon capture is turning out to be just another great green scam' (Monbiot 2008).

above combines five specific shortfalls: cost, risk, efficiency, viability and legality.

First, the economics of CCS do not add up. Estimated marginal abatement costs of hypothetical projects vary from $31 to £300 per tonne of CO_2 (tCO_2).[6] Few economic evaluations of actual CCS projects have been conducted. However, one study of a gas-fired power plant in Norway suggests costs greater than $300 per tCO_2: 'about 20 times the international carbon emission allowance price and many times higher than alternative domestic climate measures' (Osmundsen and Emhjellen 2010). The costs increase for retrofitted CCS plants (McKinsey 2007), which would dominate the UK market (DECC 2010). Aside from high capital and operation costs, the reliance of CCS plants on carbon credits may create incentives for the 'venting' of CO_2 if the price of carbon drops (Haszeldine 2009).

Second, CCS is a high-risk option**.** The technology has yet to be tested on the industrial scales required to make a dent in the UK's annual emissions. 'Slippage', where progress is hampered by continual setbacks, has been identified as a problem by the Committee on Climate Change. CCS may have limited capacity to help decarbonisation through the 2020s even assuming major projects such as Longannet had succeeded (CCC 2010). CCS plants take many years to construct even without the teething problems experienced by test plants (Russell and Markusson 2012).

Third, emission savings from CCS plants may be less than expected due to lifecycle impacts. These include carbon embodied in the manufacture of compressors, chemicals required to capture the CO_2, and the reinforced steel pipelines needed to transport the CO_2 to suitable geological structures (IPCC 2005). Efficiency losses affect CCS plants (IEA et al 2010), resulting in coal-fired power plants requiring 24–40 per cent more fuel for the same amount of final energy output (IPCC 2005: table 8.3a). Because coal mining is associated with emissions of methane, this could lead to an *increase* in the total emissions of a potent greenhouse gas. This is also undesirable for energy security.[7]

Fourth, even assuming suitable geological formations exist nearby, ready to accept thousands of tonnes of compressed CO_2 each day, each of these issues above is severe. However, recent research casts doubt on the idea that geological formations are available to safely retain CO_2 on the scale required (Ehlig-Economides and Economides 2010, Shukla et al 2010).

6 Costs have been estimated by a range of studies. These include estimates reported by the IPCC (2005): $31 to 71 tCO2 and DECC: £100-300/tCO_2 by 2050 (quoted in Harland et al 2010).

7 The UK's coal imports are double its production (Scrase and Watson 2009). Imports would increase if coal plants fitted with CCS became a major source of new electricity generating capacity, as proposed by the Committee on Climate Change (CCC 2010).

Finally, further impediments are related to the legal status of CO_2 deposits, insurance responsibilities, and the availability of low-cost fuel imports needed to power CCS-fitted power plants.

These considerations demonstrate that funding CCS is ill-advised. However, how facts are framed is often more important than the facts themselves in political debate (Lakoff 2004). For this reason, technical details should not overshadow the wider issues of morality, inequality, and energy-intensive lifestyles associated with CCS. Science should provide an objective foundation for informed discussion, not 'the final answer'. Any comprehensive debate on CCS should also include alternatives: setting aside CCS can usefully be seen as an opportunity to re-evaluate UK energy policy priorities.

Alternatives

Given the large political investment in CCS, it should come as no surprise that politicians expect 'serious international and economic implications' if it fails (Nichols 2011). The recent collapse of the Longannet CCS scheme – backed by £1 billion of government money – led to soul-searching from corporate, political, and environmental commentators (Gersmann and Harvey 2011). Such pessimism is misplaced: a grim outlook for CCS does not mean a grim outlook for all climate and energy strategies. It can be seen as an opportunity.

The time and investment currently earmarked for CCS could be spent on alternatives, which perform better in terms of emissions, energy security, and the economy. A framework for joined-up thinking about energy policies and, crucially, for prioritising investment, is provided by the 'energy hierarchy' (figure 2).

Figure 2: The energy hierarchy, as advocated by the Institute of Mechanical Engineers

SUSTAINABLE

Priority 1:	Energy conservation. Changing wasteful behaviour to reduce demand.
Priority 2:	Energy efficiency. Using technology to reduce demand and eliminate waste.
Priority 3:	Exploitation of renewable, sustainable resources.
Priority 4:	Exploitation of non-sustainable resources using low-carbon technologies.
Priority 5:	Exploitation of conventional resources as we do now.

UNSUSTAINABLE

Source: ImechE 2009.

The energy hierarchy implies that a break from the existing (growth-centred) approach to energy policy is needed, based on a clear vision of a low-energy future (ImechE 2009). The framework accepts any conceivable energy policy, from CCS (which fits into priority 4) to carbon rationing (priority 1). It encourages all the options – technical and legislative – to be 'laid on the table' and considered together. It encourages diverse and mutually reinforcing measures to be pursued in tandem, so a coherent energy strategy can be developed. As well as providing useful categories, the energy hierarchy arranges the available options in order. This is important in ensuring the most effective measures are prioritised. This differs from the thinking behind CCS and its focus on 'golden bullets'.

The mix of policies required to bring about a low carbon future in a socially acceptable way is open to debate. However, the government's botched support for CCS provides important lessons; policies should be based on evidence rather than rhetoric, on past experience rather than wishful thinking. The diversity of options raises the following questions: what would a comprehensive energy strategy, based on the energy hierarchy look like in practice? Which policies would be prioritised?

Many measures in priorities 1 and 2 of the energy hierarchy exist that are more cost-effective, reliable, and faster to implement than CCS. Priority 2 means simply improving the efficiency of buildings, vehicles and appliances. The resulting measures are likely to be attractive politically because they require no change in behaviour. Options include improved regulation of the energy performance of buildings by strengthening implementation of the EU's energy certificate, offering very low marginal costs or negative abatement costs (Boardman 2007) and furthering the use of vehicle emissions bands to discourage 'gas guzzlers' (Ryan et al 2009).

Priority 1 measures cost even less to implement because they require no change to existing technology. Energy conservation implies a change in behaviour and may therefore be seen as more risky politically. Energy rationing has the potential to reduce emissions rapidly in a socially equitable way (Fleming and Chamberlin 2011). More modest legislative changes encouraging energy conservation include fiscally neutral modifications to farming subsidies (Harvey 2008) and rising block energy tariffs (CCC 2009).

These options may not be as grand as CCS, but offer better value for money and can work in synergy. Insulation combined with policies to penalise energy waste is a good example (Boardman 2007), with very low or negative abatement costs. Various insulation measures, including insulated doors, windows and lofts, are associated with negative abatement costs: they pay for themselves (DECC 2011).

A major advantage of 'demand side' measures is that they make 'supply side' solutions easier to implement, due to lower energy use (MacKay 2009). Conservation measures to promote more flexible electricity demand, for example, would aid the integration of renewables into the National Grid (Bouffard and Kirschen 2008). Reducing energy wastage – in parallel with efficiency and improved supply-side technology – is a central tenet of the energy hierarchy, and in this sense it follows the waste hierarchy. By illustrating the full range of options the energy hierarchy also encourages finding the best value for money. For example, the £1 billion saved through the collapse of the Longannet

CCS scheme could be used to restructure electricity tariffs, so that they penalise waste whilst reducing levels of fuel poverty (Boardman 2010).

The energy hierarchy encourages a wide perspective. Including energy policy within a wider remit of taxes, well-being and equality has a huge potential to produce win-win scenarios. Improved health *and* emissions outcomes due to cycling policy (Woodcock et al 2007) and aforementioned fuel poverty policies are just a couple of examples. Such measures are 'low-hanging fruit' that can be implemented rapidly at comparatively little cost. They should be prioritised, especially in these times of fiscal contraction.

Conclusion

The energy hierarchy approach to energy policy can meet the aim of CCS (reduced greenhouse gas emissions) with lower risks and at a lower cost. Energy conservation and efficiency measures tackle associated problems of resource depletion, energy security and recession: these are issues that CCS could make worse. This is the advantage of treating the problem – our inability to stop burning fossil fuels – at its root. Rather than relying solely on 'techno-fixes' such as CCS or geo-engineering to tackle emissions, the energy hierarchy places CCS in its wider context and considers the demand side. The energy hierarchy encourages the selection of options that are cost-effective, simple, and fast to implement.

The energy hierarchy does not, however, encourage a focus on 'golden bullets'. A range of measures, from regulation of light bulbs to research into fusion, must be pursued in parallel to tackle the energy/climate problem in the long term; research into carbon sequestration options can be part of the mix. However, the current government strategy, which uncritically assumes that CCS *will* work based on scarce evidence and subsequently diverts public money and attention into large and risky schemes, amounts to placing the nation's future energy options in one weak basket. For a sure energy future, policymakers should take heed of the evidence and prioritise conservation, efficiency, renewables, and only lastly research into riskier options such as CCS.

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