

Regulation for CCS beneath the UK offshore and onshore: deep geological storage and sequestration of CO₂

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Summary:

The UK is partway through a process of evaluating the legal and regulatory and finance issues influencing CCS. These include: definition of the natural and engineered storage system, licensing, operation, abandonment, and liability. The interaction of international, EU, and UK laws for onshore, and especially offshore, CO₂ storage activities, are discussed. Additional known unknowns include the attitudes of NGO's and diverse publics. The process is being driven by the imperative of climate and ocean damage on the one hand, and the challenge of crafting a robust, fiscally prudent and effective regulatory regime on the other.

Introduction

A combination of forces has brought CCS to the fore of the UK agenda since 2001. The Government has committed to aggressive CO₂ targets well in excess of its Kyoto obligations. Kyoto targets in the UK are expected to be met with ease, largely as a result of the one-off UK fuel shift from coal to natural gas in the electric power sector over the course of the 1990s. The Government, in its manifesto has set a target of reducing CO₂ emissions by 20% below 1990 levels by 2010 and the 2003 Energy White Paper set a 60% emissions reduction target by 2050 (2003 White Paper ref). During the UK's G8 presidency in 2006, Prime Minister Tony Blair set climate change as one of the two major issues to be addressed. The urgency has been highlighted most recently by the Stern Report, which the Prime Minister has described as "the most important document about the future" he had read since becoming Prime Minister (Number 10, 2006). At the same time, the prospective decline in North Sea oil, and especially gas, production has led to increased interest in both energy security, and in the potential for enhanced oil recovery. This decline has implications for both the sustainability of Scottish regional development and for the infrastructure needed for injection. In the absence of clear actions to extend production, the infrastructure, which would be used for EOR or CO₂ storage, has already started to be removed, and will continue to be dismantled over the coming decade.

The sense of 'crisis' in the energy and especially the electricity sector is exacerbated by the imposed phase-out of coal generation as a result of the EU SO₂ directive, under which 40% of UK coal-fuelled electricity capacity will be retired by 2015. In addition there is the impending decommissioning of a large share of nuclear generation capacity without an agreed or mandated or costed re-build programme, and the rising natural gas prices and recognition (and fear) of increased reliance on Russian and Middle Eastern supplies. In a UK domestic context, the Budget 2006 Report states that CCS is "likely to be a critical technology in global carbon reduction strategies, particularly for countries with fast-growing economies and rapidly growing fossil fuel consumption". The Budget 2007 committed the UK to a competition to build the first UK electricity generation plant with CCS.

The paper is organised as follows: first, a description of the storage system in the UK, then a review of three levels that impinge on CCS activities in the UK: (i) international guidelines and

regulations, (ii) European Commission activities and directives, and (iii) the UK context including a discussion of the activities to date of the interdepartmental regulatory taskforce.

The Storage System

To retain CO₂ in the deep geological subsurface, locally engineered injection for storage, must be combined with natural features which are barriers to the return of injected CO₂ towards the surface. The time periods expected for retention are variously asserted to be decades, to the more realistic timespans of tens thousands of years (derived from climate modelling).

In the disposal of radioactive waste, there is a clear distinction between the engineered Near Field, and the less controlled natural Far Field. Leakage is not considered to impact the biosphere or humans until a near-to-surface position is reached. In a similar way, conversations on CCS regulation (IEA 2006) explicitly consider the CO₂ storage system to include not just the reservoir and immediate seal, but also the entire overburden sequence of rock.

There is an unfortunate and unhelpful imprecision in legal consideration of the subsurface, in that phraseology can envision the “subsoil” and everything beneath that as a homogenous, and can also envision the CO₂ “merging to become part of the subsurface”. This may easily produce confusion and litigation in the future – for example if CO₂ leakage occurs from Site A and moves laterally so as to appear to be derived from Site B. It is suggested that an engineered Near Field for CO₂ can be considered as the injection borehole and its sealing, the aquifer or hydrocarbon reservoir into which CO₂ is injected, and the natural and engineered local seal to that reservoir. The Far Field comprises the overburden (usually a sequence of layered sediment) and any additional boreholes intersecting overburden, seal, and reservoir. This Far Field includes all the subsurface, possibly with a “leak” becoming important at the shallow depths of penetration for agricultural wells extracting water, and a ‘leak’ certainly being important where it impacts on drinking water aquifers, the soil, and land surface or seabed.

Throughout this article, much of the detailed and specific legislative instrument information is drawn from DTI (2007), except where otherwise referenced.

International Guidelines and Regulation

The UK takes international treaties and guidelines very seriously, and usually moves to formally incorporate international legislation into UK domestic law. These include Integrated Pollution Control Directive, marine law and European Commission (EC) Regulations and Directives. Where relevant, the IPCC and UNFCCC guidelines and standards for CCS will presumably become incorporated into UK standards.

There remains some debate amongst EU member states about whether CO₂ can be regarded as a waste, an industrial product, or as a resource. The UK position is very clear that CO₂ will be regarded as a waste. UK regulation discussion is only concerned with storage of CO₂ beneath the UK landmass or within UK territorial waters out to 200 miles. A formal declaration and definition is planned for 2008 to enable the federal Westminster government to legislate and regulate pore space deep beneath the offshore North Sea, as at present such power has not formally been claimed.

The UK has also taken a lead in The UK has also taken the lead in sponsoring overseas CCS projects including the nZEC (near Zero Emissions Coal) or COACH (from the EU) development

of a CCS plant in China) 3.5M GBP. However, the UK does not appear to be formally concerned with regulation for overseas CCS projects which it may be co-sponsoring).

IPCC and UNFCCC

The UK Government follows the 2006 Inter-Governmental Panel on Climate Change (IPCC) guidelines for greenhouse gas (GHG) inventories. Specific details are in Volume 2, Energy Chapter 5: CO₂ transport injection and geological storage. This includes recommended methodology for site characterization before storage occurs. There are also recommendations and information to assess proposed pathways for leakage. The UK position will be to assess the risk of leakage, via computational forward simulation and modelling and site performance. It is very unlikely that an absolute criterion of “no leakage” will be adopted, rather a site performance criterion will be used, to match against predictions made by a site Operator during the licensing application. International guidelines will also be taken on plans for monitoring. Monitoring can be considered as three phases: 1) during site Operations, 2) at Closure, 3) during a Liability period after site Closure (DTI 2005). An essential preface to site licensing will be a comprehensive assessment of baseline geological and fluid conditions. The precise parameters for this have not yet been set. For climate change mitigation purposes, it is probable that storage credits for CO₂ will be available at some future time, when CCS is included in the EU-ETS and/or UNFCCC CDM system. It will be essential to verifiably report CO₂ injected, fugitive emissions during the CO₂ supply and injection chain, and undertake monitoring to assess CO₂ movement in the Near Field and Far Field. At present only CO₂ escape from the Far Field (rather than Near Field) seems to qualify for penalties of emission credits, after injection has occurred.

The existing CDM framework under the UNFCCC is not readily suitable for CO₂ storage, because the timescales do not appear to fit. At present, CDM credits for CO₂ can either be claimed for each year for one set time period of 10 years, or two periods of 7 years each (with the review after 7 years to re-set the allowable yearly CO₂ certified emission reductions). But in CCS cases, these timespans will only address failures of engineering such as pipework failure or borehole sealing; any geological seepage will occur on much longer time scales. It is not clear how to handle these long-term risks, and indeed it is not clear how different timescales can be matched (e.g. of 100 year forestry versus 10,000 year CCS). Should a given sum be estimated and subtracted in the existing CER period? Accounting may need to be undertaken annually for emissions trading such as EU-ETS, as purchasers of CCS-electricity would not be liable to spend their emissions permits. Alternatively, an annual “loan” of emission reduction could be designed, with a final retrospective account balancing at the final handover of any site from Operator to Government. Or is a much longer CER crediting period needed for CCS projects? This last method would make CCS more economically viable. A simple leakage criterion, such as the much – quoted 1% in 1,000 years, is not at all helpful, because this does not consider different sub-surface settings, nor does it consider that seepage mechanisms can retain CO₂ within the Far Field for thousands of years, whereupon a surface leak could become apparent.

On 6 March 2007, an alliance of 50 large UK industries and NGO, led by DEFRA and DTI issued a Manifesto for the EU-ETS, including a call for CDM and JI projects to be eligible for EU-ETS credits

Marine Treaties

The great majority of CO₂ storage potential close to the UK lies beneath the North Sea and Irish Sea. Consequently it is vital that CO₂ storage has a position of being clearly allowed by the relevant offshore legislation. Any legal, or regulatory, uncertainty will be viewed as an

unacceptable risk by commercial companies. That could lead: firstly to precautionary dismantling of the existing offshore infrastructure, secondly to a lack of investment in a CCS future. The two main marine treaty regimes of interest are the global 1972 London Convention and its 1996 Protocol, and the regional OSPAR convention

London Convention

The London Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter is a global agreement which regulates disposal of waste and any other material at sea. The 1972 Convention has been ratified by 81 countries including all of the European Union. Because dumping excludes placements for purposes other than the mere disposal of waste, it is likely that if CO₂ were to be injected for an industrial purpose (such as EOR) or for scientific research then it would be permitted under the Convention (SwedPower/Vattenfall, 2004).

The 1996 London Protocol, which was intended to modernise and ultimately replace the London Convention entered into force on 24 March 2006. and to date has been ratified by 29 nations including the UK. The Protocol adopts a more explicitly precautionary approach. The new definition of 'dumping' reads: “*Any storage of wastes or other matter in the seabed and the subsoil thereof from vessels, aircraft, platforms or other man-made structures at sea*” and therefore the Protocol is seen as more directly relevant to CO₂ storage (IEA, 2005). Moreover, the Protocol prohibits any dumping except for acceptable wastes contained in a 'reverse list'. Although specific exceptions can be given for pipeline discharges from land, and operational discharges from vessels or offshore installations. Consequently, the London Protocol appeared to prohibit the general storage of CO₂ both in the water column and in sub-seabed repositories (IEA, 2005).

An amendment to Annex 1 of the London Protocol was proposed in April 2006 by Australia, and was co-sponsored by the UK, Norway, France, and Spain. At the 28th Consultative Meeting on November 2, 2006 the amendment was adopted, and came into force on February 10, 2007. This amendment enables storage of CO₂ beneath the seabed. This is paraphrased as comprising: “CO₂ streams from CO₂ capture processes for sequestration are permitted: 1) Only if these are injected into a sub seabed geological formation. 2) Only if these consist overwhelmingly of CO₂, although these may contain incidental associated substances derived from the source material and capture and sequestration processes used. 3) Only if no wastes or other matter are added for the purpose of disposal. Detailed guidelines for waste assessment relevant to CO₂ disposal still need to be completed during 2007 by the OSPAR group. The discussion on a meaning for ‘overwhelmingly’ will be important, as will the consideration of substances associated with the CO₂ (eg SO₂ could be a technically legitimate by-product from a coal power plant), which are already regulated to reduce cross-border transmissions. In the UK this work has been led by a specially-formed cross-government team from the Department of Environment, Food and Rural Affairs (Defra) and the Department of Trade and Industry (DTI).

The global reach of the London Convention, has created a perception in the UK that this is the key superior worldwide Convention, although the regional OSPAR Convention will also be proposed for adaptation (see below).

OSPAR

The OSPAR (Oslo-Paris) Convention (1992) is a regional marine treaty, ratified by 15 states and the European Commission, which prohibits pollution of the Northeast Atlantic Ocean. A report

by the OSPAR Commission's Group of Jurists and Linguists (2004) offered a preliminary view on the acceptability of CO₂:

- Discharge by pipeline into the maritime area from land-based sources is not prohibited but must be strictly regulated or authorised.
- Dumping from vessels is prohibited, unless for the purpose of scientific experimentation.
- Placement of CO₂ arising from the operation of an offshore installation for the purposes of EOR, climate change mitigation or mere disposal is not prohibited but must be authorised or regulated;
- Placement of offshore-derived CO₂ for scientific research is not prohibited but must be in accordance with the Convention;
- Placement of onshore-derived CO₂ brought to an offshore installation is permitted for experimental or EOR purposes, but is otherwise prohibited.

Annex 2 of the London Protocol specifies materials, which can be disposed, and exceptions are specified. An amendment to allow CO₂ from CCS to become a permitted exception has been drafted, and will be proposed at the June 2007 OSPAR meeting.

European Commission Activities and Directives

Within the European Commission, at least four Directorates have interests in CCS: Environment, Transport and Energy (TREN), Industry, and Research. During 2005- 2007, there has been intense activity within the Commission, to enable CCS to come forth as a very large potential technology. This is one strand enabling the EU to attain its objective of restricting climate change to a 2 C maximum increase.

On 10 January 2007, the EC issued a Communication with an integrated Energy and Climate Change package (EC 2007), calling for a 30% cut in GHG by 2020. This includes a 20% target for electricity generation from renewables, 10% biofuel use in transport, and 20% energy efficiency gain. Nuclear power remains for individual states to decide. The CCS aspects are part of the ZEP, with an ambition for compulsory CCS on all fossil fuelled electricity plant after 2020.

Objectives of the legal framework for CCS within the EU (EC 2006b) include: 1) removal of unwarranted and potential barriers for application of CCS. 2) Creation of new rules assessing environmental risks from long-term CO₂ storage (i.e. site selection, licensing, monitoring, verification, remediation, and liability). 3) Examination of incentives to enable inclusion of CCS within the EU-ETS. 4) Treatment of CCS developments under state aid rules.

The Power generation and CCS industries have also undertaken significant work during 2005-07 in the launch of the Zero Emissions Fossil Fuel Power Plant (ZEP) Technology Platform, which produced two reports in 2006, a Strategic Research Agenda (SRA) and a Strategic Deployment Document (SDD) (ZEP, 2006). Based on this work, the publication of the EC strategic energy review (EC Jan 2007), was at D.G. Commissioner and EU President level. Part of this aims to develop a favourable regulatory framework for CCS, to aspire to 12 full-scale demonstration plant by 2015, to make all new Coal plant retro-fittable for CCS, and to enforce CCS on all new plant from 2020. A transport network of pipelines may start construction from 2010, to be functional by 2020. An EC Communication on "Sustainable fossil power" (2007) commits to a consistent regulatory framework across the EU by removing barriers and amending Directives, or choosing new legislation to create a free standing CCS framework. CCS will be considered for inclusion from 2008 in EU-ETS Phase II (individual plant can already apply to be included

within EU-ETS under the existing legislation). There is an aspiration to include CCS in EU-ETS from Phase III (2012).

The UK Government has assumed a leading role in the development of the EU's CCS strategy through its support for the FENCO project (FENCO) and in chairing the Mirror (government) Group of the Technology Platform. UK industry and academia is well represented on the five working groups that are charged with developing the EU strategy. (HoC 2006b para 17)

EC Directives which currently pose challenges to the deployment of CCS technologies include: Water Framework Directive, which prohibits discharge from saline aquifers into ecosystems, or shallow depth water use. The Landfill Directive operates for onshore CO₂ storage, and means that CO₂ storage could be taxed as a waste, rather than receiving benefit for storage. Additionally CCS needs to be included under the Waste Framework Directive to enable a permit system. Additional work also needs to be undertaken on safety of the CO₂ transportation network. Existing EU frameworks, which could be used or adapted, include the SEVESO II Directive (dangerous substances), the Environmental Impact Assessment Directive (97/11/EC), and the Integrated Pollution Prevention and Control Directive (96/61/EC). DG TREN (energy) predict that coal generation within the electricity mix (EC TREN 2006) will increase from 180,000 MW in 2005 to 280,000 MW by 2050 (EC TREN 2006).

In Europe, pore space is owned by the State and, therefore, utilisation is addressed in the licensing process. The Carbon Sequestration Leadership Forum (2004) report on regulation identifies the need for property rights to also be clarified in relation to CO₂ transport. In this context, the issues involved are: (i) facilitating third party access to pipelines; and (ii) providing certainty in property rights for pipeline owners and users through some form of licensing regime.

UK

The development of CCS technology in the UK is led by the DTI (Industry). Additional work on the possible commercialisation of CCS has been carried out by the Treasury, relating to financial instruments, incentives and grants (Treasury Consultation, 2006). The regulation and licensing aspects are being tackled by a cross government Task Force specific to CCS, and including members from DTI, DEFRA, Health and Safety Executive (HSE) and the Environment Agency (EA). The aims of this are to facilitate and regulate the development of CCS as part of a UK portfolio of actions in mitigation of climate change and ocean acidification. Key objectives are to reduce or remove blockages and uncertainty for both industry and regulators involved in CCS, and to ensure the environmental integrity of CCS. The development of CCS will also be monitored and regulated by the HSE, who are in the process of examining CO₂ - specific issues with onshore pipe transport, and high-pressure CO₂ operation on offshore installations. The petroleum Act may affect property rights onshore and offshore, but the position is not yet clear.

UK Offshore Storage

Three circumstances are envisaged for offshore CO₂ injection and storage: 1) enhanced oil recovery (EOR), 2) injection into depleted oil or gas reservoirs, 3) storage in saline deep aquifers. The issues relating to EOR are considered to be adequately covered by existing petroleum regulations (but some specific HSE issues are still being studied). EOR is permitted by OSPAR as a "working fluid" to help produce hydrocarbons.

Regulation:

For offshore regulation, the OSPAR treaty needs to be modified, and the Crown needs to declare rights to pore space within rock out to a 200 mile limit, under the UNCLOS convention. There has been pressure from some advisors and industry to create a new CCS Agency or Regulator (House of Commons 2006), where all issues are considered and decided within one organisation. This possibility is still under consideration by UK Government, but a more pragmatic, rapid, solution may well be to create the minimum amount of new or amended legislation initially, and so to extend existing provisions. This must additionally enable the possibility of CO₂ capture offshore from Associated Gas, with re-injection of CO₂. The UK is also considering issues arising from multi-user sites, possibly by competing Operators within one geological aquifer. Most of the issues being considered are similar to those relating to oil and gas development, and some synergy exists with projects for methane gas storage. Specific issues for CCS include: the need for monitoring during and after site operations, the deferment of decommissioning for offshore installations and pipelines, and decommissioning after operation as a CCS site.

Issues of planning zoning may also arise in the subsurface, particularly for onshore or nearshore areas. Structures with good retention capacity could be used for either CCS or for methane gas storage. These will probably be economically determined by profit motives. A potential resource conflict of saline aquifer use could arise, to prevent use for CO₂. Most probable is the competition between companies seeking to use deep coal beds to adsorb CO₂ during ECBM, versus the longer term resource potential of the same coals for Underground Coal gasification, to use as fuel – in which case adsorbed CO₂ would be undesirable.

Where CO₂ injection from several sources occurs into one saline aquifer, or into depleted oilfields within several km distance, then leakage of CO₂ at a future date will need to be remediated by one or more of the Operators. To enable this to occur, then it will be advantageous if CO₂ can be geo-chemically fingerprinted by addition of small quantities of tracer compounds, such as specified noble gas, or isotopically labelled CO₂ or methane. Parts per billion of such compounds will remove ambiguity in identifying leaked CO₂ – and some compounds can also give early warning of leakage.

The ultimate ownership of CO₂ seems inevitably to become destined for Government, although precisely how long after site closure this occurs has not yet been decided. Existing regulations include :

- The Petroleum Act 1998 (covering site identification, drilling, consenting, Operator appointment, injection, interaction with other sea users, record-keeping, restrictions on assignment).
- The Food and Environment Protection act 1985
- The Coast Protection Act 1949 (but these all are not designed for long-term operations).
- The EC Habitats Directive 1992,
- The Strategic Environment Assessment Directive (2001/42/EC).
- The Health and Safety at Work Act 1974.

Marine Conservation

In terms of marine habitat, the UK may encounter planning zonation and other wildlife agendas, in an intensively multi-used shallow shelf sea. The Marine Consents and Environment Unit (MCEU) is responsible for the licensing of any works at sea or in tidal waters around England. In Scotland and Northern Ireland consents are granted through the Scottish Executive or Department of the Environment (NI). Where works are linked to the offshore energy sector MECU works together with the Licensing and Consents Unit of the Department for Trade and Industry. To grant consent MECU has to be satisfied that appropriate measures are to be put into

place to satisfy a number of pieces of legislation. These include the Food and Environment Protection Act 1985 Part II (Deposits in the Sea). This Act was intended to

- Protect the marine environment and the living resources it supports and human health
- Prevent interference with legitimate use of the sea.
- Minimise nuisance or noise arising from waste disposal.

This legislation has subsequently been modified by a number of other acts; the most relevant to the impact of CCS operations on the natural environment are listed below.

- Waste Management Licensing Regulations 1994. This stipulates that unless there is a practical land-based alternative, waste may not be dumped in the sea.
- The Conservation Regulations 1994. The MCEU must be satisfied that any project under consideration must not have a significant impact on any site (Special Protected Area (SPA), candidate SPA or any Special Area of Conservation(SAC)). This legislation is underpinned by the Berne Convention (The Convention on the Conservation of European Wildlife and Natural Habitats) which came into EU law as the EC Birds Directive and the EC Habitats Directive.
- The Petroleum Act 1998. Consents are needed for the installation of pipelines and cables and licensing is needed for the disposal of drill cuttings and produced waters.
- Countryside and Rights of Way Act 2000. Approval is needed from Natural England if operations will damage flora, fauna or any other feature within a site of special scientific interest (SSSI).

In some cases planning developments may also be affected by :

- Wildlife and Countryside Act 1981. This is UK law stemming from the Berne Convention. This influential convention also led to the EU Habitats Directive and the EU Birds Directive. The Act protects certain listed species such as cetaceans, and basking shark from intentional killing, injury and in some cases disturbance. It also enables the establishment of Marine Nature Reserves and Sites of Special Scientific Interest.
- Conservation (Natural Habitats & c.) Regulations 1994. These require the implementation of a range of species protection measures and the surveillance of habitats and species. Species protection is undertaken by the creation of a network of specially designated sites. It is important to note that the Conservation (Natural Habitats & c.) Regulations 1994 (Habitats Regulations) only apply up to 12 miles offshore thereafter protection is offered by Offshore Petroleum Activities (Conservation of Habitats) Regulations.
- Offshore Petroleum Activities (Conservation of Habitats) Regulations give protection equivalent to the Habitats Regulations to areas in relation to oil and gas activities on the UK continental shelf and nearby waters.

Decommissioning and Liability:

Offshore oil and gas facilities typically comprise extremely large production platforms, linked to one or more pipelines receiving hydrocarbon, and dispatching oil or gas to a landfall terminal. Existing legislation, under the Petroleum Act 1998 Part IV, requires Operators to retain future liability in perpetuity for all structures, and to bear costs of decommissioning and deconstruction. Some vintages of oilfield may have costs which can be offset against exploration or production costs elsewhere in the UK. This Petroleum Act legislation includes equipment for EOR. Part of the financial attraction for oil companies to engage in CCS offshore, is the deferment of such decommissioning costs, which could be UK £400- 800 M (\$800 -1,600M). Sale to a new Operator would transfer such liabilities. There is no existing legislation which

regulates the decommissioning of additional CCS equipment. Existing U.K. domestic legislation includes

- The Petroleum Act, 1998 part IV.
- Food and the Environment Protection Act 1995 (FEPA).
- Pollution Prevention and Control Act 1999 (PPC).

In the UK the PPC regulations may provide an interim solution for long-term de-commissioning and liability. International law includes:

- The EU Environmental Liability Directive (to be UK law by 30 April 2007).
- London Protocol to London Convention.
- OSPAR.
- UNFCCC.
- Second European Climate Change Programme.

Long-term ownership

There is a widespread recognition that longer-term ownership of CO₂, should pass at some stage to the government. No commercial organization can make indefinite guarantees of liability or continued existence, and so commercial competitors are uniformly of that opinion. When should liability transfer from industry to the State? From the State perspective, this is when liability into the future has been guaranteed as a practical minimum – as the State is guarantor, not insurer.

Such a decision can be informed by experience from hydrocarbon production. In some oil and gas producing areas, notably Alberta, Operators contribute to a mutual insurance fund which provides remediation for “orphaned wells”. Producers of electricity from nuclear power stations in the UK now pay a levy to provide for long term decommissioning and waste disposal. The risk of leakage from boreholes is frequently cited as one of the most probable CO₂ pathways. To evaluate this for offshore North Sea boreholes is difficult, as no data has been compiled. In any case these are de-pressurized installations after oil production, rather than re-pressurized installations after CO₂ injection. Densely drilled offshore areas with good databases do exist, again Alberta. Historical compilation shows (GHGT 8) that one in 3 wells have leaked and this usually occurred within 10 years of first drilling. The same dataset also shows that after legislation was tightened, then operators improved their well sealing, so that fewer than one in 10 boreholes subsequently leaked. This suggests that sealing off CO₂ injection boreholes is a problem with an achievable remedy, if legislation is sufficiently strict, even though new cement materials need to be developed to withstand CO₂ corrosion. Leakage from existing boreholes is most likely to become apparent during the 20 years during operation of an EOR or aquifer injection facility, and so will occur during the liability period for a site Operator. As part of a licensing regime which will engender public confidence, we suggest that liability for leakage from the Near Field, or through boreholes, be extended to run for, say, 20 years after a facility decommissioning date. If monitoring during that time shows that the site performance has continued to be as predicted by the Operator’s model and license application, then the State can take over liability, with minimal risk. It will be an issue for the Government to decide on what quality of monitoring it needs, to produce a reduction of future risk through high-quality prediction. Examples also exist from analogue sites where fluid CO₂ occurs naturally in deep subsurface pores. Because CO₂ is not pressured above equilibrium for any depth in these sites, even if CO₂ leakage occurs to the surface, then natural analogues show that leakage will be at slow rate, producing only local sites of CO₂ emissions at the surface.

How to enact new rules

Methods for enacting new legislation are being considered in order to gain Parliamentary time within the forthcoming Climate Bill Marine Bill, or the Energy Bill. These all provide for cognate legislation, where CCS additions could be accommodated, to be enacted before 2011.

UK Onshore Plant and Transport and Storage

Capture Plant

Building of new power plant, coal or gas, is licensed and consented to under Section 36 of the Electricity Act 1989. Plant of more than 50 MWe is centrally controlled by the Secretary of State for Energy, whereas plant of less than 50 MWe is controlled by the local Planning Authority. The building of “capture ready plant” will be specified within the EU, however a clear definition of this will soon be needed, to be considered as part of the Section 36 consenting process.

Environmental standards within the boundaries of the power plant site, are enforced by the Pollution Prevention and Control Act, through the Scottish Environmental Protection Agency, or through the Environment Agency for England and Wales. Health and Safety aspects are partly controlled by Hazardous Substances Regulations within planning and also by the Control of Major Accident Hazards regulations (COMAH), as with refineries or natural gas storage. A desk study was undertaken for UK DTI by DNV (DTI 2003) to identify the risks during each part of the CCS chain. However the UK HSE has raised concerns about the behaviour of supercritical CO₂, particularly at pressures reaching 200 atmospheres onshore, or 400 atmospheres on offshore platforms. Supercritical CO₂ may yet be defined as a hazardous substance within the U.K. Engineering experiments have been conducted in 2006 by the HSE with British Petroleum, to observe the effects of catastrophic supercritical CO₂ releases and explosions within plant, or from fractured pipework.

Transport

Transport of small quantities of CO₂ by road or rail is covered by existing duty of care regulations, supplemented by waste regulation. However for routine transport of large volumes, the expectation is that dedicated pipelines will be built to transport large volumes of CO₂ onshore. If these are more than 10 miles in length, then licensing under the Pipelines Act 1962 is required by the Secretary of State for Energy. Reuse of existing pipelines (onshore or offshore) has been suggested (East of England Energy Group). Such re-use would need a re-licensing procedure to change the pipeline specification of the substance to be conveyed (e.g. from methane to CO₂). Ancillary plant, such as compressors, would be licensed by the Local Authority.

Onshore Storage

Although the largest potential storage volumes in the UK are offshore, there is considerable interest in onshore storage, particularly close to point sources of CO₂ sources, such as large power plants (DTI 2006).

The activities of site selection, environmental impact assessment, construction, operation, closure, monitoring, and remediation are similar to those enacted offshore, or for onshore hydrocarbons. Any modifications can be adapted from existing subsurface legislation within the Petroleum Act. A key difference for onshore storage is the application of the Town and Country planning system, through Local Authority planning departments, who may have minimal competence in CO₂ storage. A range of largely EU-driven regulations will apply to onshore storage including:

- EU Waste Framework Directive (75/442/EEC, modified by 91/156/EEC)

- Landfill Directive 99/31/EC
- Integrated Pollution Prevention and Control Directive
- Groundwater Directive 80/68/EEC
- Water Framework Directive 2000/60/EC
- Habitats Directive 92/43/EEC
- SEVESO II Directive 96/82/EC

A critical challenge is that the EU Landfill Directive basically prohibits the disposal of either liquids or gases into, within, or onto land. It may be possible to undertake EOR under Petroleum Act regulations (as with methane gas storage). But it is possible that a strict interpretation would require CO₂ capture and injection to occur on the same site. We suggest here, that onshore storage could be investigated in an interim sense, using the same approaches as for methane gas storage – where the intention would be to remove the CO₂ to an offshore site at some future time after a pipeline connection had been constructed.

Conventional remedies for this legislative conundrum could include: 1) A new CCS directive from the EC, 2) explicit changes to the EU Waste Directives, to enable CO₂ storage, 3) dis-applying the Waste Framework directive for CO₂. Work on this continues.

There is a strong incentive to enable onshore CO₂ storage within the EU because several key member states which generate large volumes of CO₂, such as Germany or Poland, do not have easy access to storage capacity within offshore saline aquifers. Possible remedies include specific exemptions from the Landfill and Waste Directives. Similar solutions can be anticipated in states with large numbers of landlocked CO₂ sources, such as USA and Canada.

Continuing UK work

A cross government department Task Force continues to work on domestic regulatory aspects. Several stakeholder meetings have already been held, and informal consultations will continue. A consultation document will be issued during 2007. Simultaneously, common regulatory principles for CCS in the offshore region are in the process of being developed by the North Sea Task Force, which is made up of public and private sector organisations from around the North Sea rim, and has facilitated cooperation, particularly between the UK and Norway. Other external drivers include the EU Energy Review and the publication of changes in EU Waste Legislation. The overall objective of UK work is to establish a legislative framework to enable demonstration plant to be built, even if this framework has an interim life.

Intellectual Property

A great deal of effort has been placed into international examination of Intellectual Property and Contractual Rights (IEA 2006). The present authors agree that such aspects will be of great significance to the commercial parties. However, few, if any, of these issues appear to be particular to CCS. The most sensitive issues for IP are probably in the design of the combustion plant, and reagents used in the capture process. Globalisation of technology has a long precedent in the hydrocarbon industry, and the same problems occur of diverse nation state attitudes to patent protection, IP, and Trade Secrets. It is the opinion of the present authors that these IP issues are too large and fundamental to solve for CCS alone.

Technology transfer also raises the question of intellectual property and contractual rights (IEA 2006). The most sensitive issues are probably those associated with the design of the combustion plant and reagents used in the capture process. To allay fears of potential investors

in overseas projects, best practice international standards must be applied to ensure that CCS developments do not pose undue safety hazards, or do not leak CO₂ within short time periods. Such international standards will be imposed for Clean Development Mechanism (CDM) projects on CCS, if and when CCS is included. Verification organisations such as Det Norsk Veritas (2006) are already advanced in specifying the sorts of standards that would be applied.

Regulatory Process

An important aspect of regulation is the regulatory process itself. Literature suggests, for example, that this process should be risk-based, transparent, inclusive, focused upon learning to reduce uncertainties, flexible to specific situations and circumstances, and so on (Shackley 1993 and references therein). The process should also be (and seen to be) strictly independent from the companies that it regulates, whilst maintaining a dialogue and continual exchange of information with those companies, so that learning is occurring on both sides. This implies high trust between companies and regulator, but also independence in their relationship and a system to scrutinise the regulator's activities. Inclusiveness requires that NGOs and other potentially critical organisations are able to express their viewpoints and to have these taken seriously (e.g. their criticisms should be responded to in detail in writing). A learning approach requires that the regulator is not merely implementing a set of written-down rules, but is fully aware of the uncertainties in the understanding of the risks and is working with industry to try and learn more about these risks. For example, a controlled 'trial and error' approach can be adopted in a regulatory environment in order to try and understand risks better.

The UK has a good reputation when it comes to its regulatory processes, though there have been some notable cases where uncertainty surrounding scientific knowledge has been downplayed and misrepresented for political and policy reasons, BSE being the cause celebre (van Zwanenberg & Millstone, 2005). What is particularly dangerous is when scientists adopt the assumptions and preferences of politicians and senior civil servants in their own interpretation of scientific uncertainties. When this occurs, as was the case in the BSE debacle, those same politicians and civil servants are able to claim that their opinions derive from the authoritative scientists whom they have consulted. In reality, such reasoning is circular, since these scientists have shaped (and often compromised) their own judgements based upon the (often oblique and implied) preferences of those politicians and civil servants. The way to avoid this seems to be to ensure that both the scientists and the decision-makers are explicit and transparent about their arguments and opinions. Some degree of public exposure of the decision-making process and outcomes helps to protect inappropriate circularity of this sort emerging. This is not to argue for full openness in all regulatory processes, however. That is not usually possible because of commercial confidentiality reasons and also because a degree of informality and protection from immediate public scrutiny is needed to help build up relationships between advisors and policy makers which are ones of trust and intelligent treatment of uncertainties.

Known Unknowns: NGO's and Publics

At the end of each CCS planning document by Industry, comes the addition of public information and engagement. This will not be examined here. We merely note that some NGO are in favour of CCS, others acquiescent, and a few are very strongly opposed. There is also a diversity of publics, who will need to be engaged and convinced, particularly for onshore developments, and indeed for onshore transport networks. It is impossible to over-estimate the ingenuity and energy of a member-organisation NGO, or a locally aggravated public. As an insight into the variability of public opposition, natural gas storage is currently being developed onshore in the UK, with developers proposing sites for licensing. In one small county

(Cheshire), one proposal received little public comment, by contrast a second close nearby was vehemently opposed. Consequently, the present authors consider that CCS development standards should be realistically high, especially for the first projects. This will avoid hostages to fortune and, most importantly, will avoid accidents or leakage.

Conclusions

The UK position on CCS regulation has advanced greatly during 2005-07, and is expected to result in proposals for adaptations to existing legislation, or specific new CCS legislation, during 2007. Enactments of existing regulations are intended to occur, by use of already scheduled parliamentary time, and will enable demonstration plant with storage offshore. Development of onshore storage is hampered by EU Directives (regarded by the UK as law), and so is contingent on either or both of: creative interpretation of existing EU Directives; or formal modification of Directives at EC level. Indications of this are expected to occur during 2007 and 2008.

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