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Discussion Paper

Challenges to the Implementation of New Technologies: the Case of Carbon Capture and Storage

Prepared by the Commission on Environment and Energy

The Need for Carbon Capture and Storage (CCS)

Both more widespread use of existing efficient technologies and the development and deployment of new low carbon technologies will be necessary for the reduction of GHG emissions in a manner that allows for the stabilisation of GHG atmospheric concentrations at a safe level. The cost of emissions mitigation is of critical importance to achieving emissions reductions without undue sacrifice of economic progress; technology development and deployment will be vital to making cost effective the full suite of mitigations options. Impediments to the development and implementation of new technologies should therefore be of great concern to those seeking a solution to global warming.

ICC believes that it is an important point of principle that the full range of technological options should be eligible for use in abating climate change. Some technologies, such as nuclear and large-scale hydro, have already been effectively excluded from eligibility under the Kyoto CDM. None should be ruled out as priori, rather they should be judged on their potential to reduce GHG emissions safely and efficiently. Policy and regulations should establish performance criteria, including environmental criteria, to be met bearing in mind that research and innovation may to deliver acceptable solutions through a variety of technological approaches.

CCS [1] is a technology with a very great potential to contribute to emissions reduction from large point sources of CO2 emissions, especially from coal-fired power plants. For instance, the IEA estimates that the use of CCS would account for 20% of the global GHG emissions reduction effort to 2050 in an active mitigation scenario relative to their Baseline Scenario where no further

[1] 'Carbon Dioxide capture and geological storage is a process consisting of the separation of CO2 from industrial and energy-related sources, transport to a geological storage location and long term isolation of the atmosphere.' 'Carbon Dioxide Capture and Storage. Summary for Policy makers and Technical Summary' IPCC, 2005. This report gives a good description of CCS.

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Document 213/48
28 November 2007

action to reduce emissions is assumed[2]. Other studies of stabilization find that CCS begins to make an important contribution to mitigation in the period around 2030, with large-scale deployment in the latter half of the century. Many countries are dependent on indigenous coal reserves to meet their energy needs and are committed to its continued use. This will necessitate the deployment of abatement technologies such as CCS if CO2 emissions from coal use are to be reduced. Should CCS fail to qualify as a recognised emissions reduction option (whether under the CDM or otherwise), the cost of achieving the required emissions reductions would increase significantly and the chances of meeting climate change goals would likely fall in proportion[3].

Recent studies[4] of the costs of climate change have emphasised the benefits of early action to reduce emissions. At the same time, a large power sector investment programme in the next twenty years is underway to replace existing plant and meet new energy demands[5]. Should the additional fossil fuel generating capacity be built without CCS or CCS-readiness, then a significant proportion of future emissions would not be able to be directly remediated, resulting in extensive carbon 'lock-in'. Over the longer term, the importance of CCS may increase further as fossil fuels that are lower in carbon content are exhausted and exploitation of tar sands and similar carbon intense resources proceeds, and as coal is used increasingly to produce synthetic fuels. CCS also has the potential to play a role in reducing industrial CO2 emissions, particularly those from large point sources such as cement and iron and steel production[6].

Commercial Challenges Facing CCS

Those attempting to implement CCS face a number of commercial challenges familiar to investors in any unproven technology that aims to serve an uncertain market. Although the component elements of the CCS technology have all been used at industrial scale for many decades, their application at a large scale for power plants is a new field and one that raises important business risks. Some of these challenges arise from uncertainties in the way the technology itself will work[7]; others arise from uncertainties in the regulatory and incentive framework that will apply; still others arise from the essential need for large-scale infrastructure with associated concerns for finance, permitting and public acceptance.

Many mitigation options, such as energy efficiency improvements, make use of technologies that serve purposes besides emissions reduction. Often , energy savings alone will justify their

[2] The IEA assumes that a global carbon price of \$25/Tco$_2$c would be available from 2030 to incentivise CCS projects (IEA, Energy Technology Perspectives 2006). The IPCC suggests that CCS might contribute between 15-55% of global mitigation effort up to 2100. (IPCC, op.cit., p11)
[3] The IPCC notes that an increase in the cost of mitigation will increase the rate of leakage from Annex 1 countries (IPCC FAR, Working Group III, Summary for Policymakers p17).
[4] A point made emphatically in the Stern Report on the Economics of Climate Change..
[5] Suggested by the IEA to be equivalent to 40% of existing generation capacity .
[6] It is estimated that about 22% of large point sources of CO2 globally are outside the power sector. (IPCC, op.cit., p2)
[7] For instance, further development work is required for gas turbines to combust hydrogen-rich gas cost effectively.

commercial use. CCS is a technology that has been designed for the purpose of reducing carbon dioxide emissions to the atmosphere[8]. In practice it is a relatively costly, energy and capital intensive technology albeit one with potential for future cost reduction. Because of higher costs, the adoption of CCS by the private sector will depend on the incentives provided by the carbon market and other emissions reduction policies that overcome the additional cost of CCS development and deployment.

As well, CCS will require development of appropriate regulations including for site selection, operations, monitoring and resolution of issues regarding long-term liability for storage. Depending on how these issues are resolved, they could have significant potential to affect CCS costs.

Carbon markets are developing rapidly and may eventually provide a sufficient commercial signal for CCS to be deployed in the countries that participate in these markets. CCS costs are dominated by the cost of CO2 capture. Capture costs have been estimated for various potential technical approaches. As well, estimates have been made for transport and sub-surface storage that may vary based on site-specific circumstances. Current indications (for instance, from the IPCC Special Report on CCS) are that a carbon price of between $30-50/tCO_2$ should be sufficient to incentivise significant potential in many projects for power plants[9]. However, cost estimates remain preliminary at this point. Large-scale demonstration projects will help identify ways to reduce costs in the future enabling more widespread implementation and could target some of the 'easy wins' whereby CO2 that is captured in the normal run of business, for example, from natural gas plants, could be incentivised to store CO2 at carbon prices lower than $20/tCO2. Large-scale demonstration plants would also play an important role in providing confidence to design CCS technology systems that will function efficiently for tasks requiring, long-term reliable supply.

Beyond the need for large-scale demonstrations to confirm operational reliability and the scope for enhanced cost-effectiveness, there are a number of challenges for project developers in having to rely on an uncertain regulatory market price as an incentive for heavily capital-intensive and long-lived projects.

1. Carbon markets are primarily designed to identify and implement the most cost effective current mitigation opportunities; they are not designed to develop more costly new technologies rapidly. This is especially the case given the very early stages of carbon market development and the great uncertainties associated with its future over a 20-30 year horizon. Greater certainty regarding the existence and integrity of these markets will be required for long term investments in R&D and deployment. Alternatively, incentive prices for CCS-using processes and other new and capital-intensive technologies may need to be

[8] Enhanced oil recovery is an exception.
[9] The IPCC Special Report (op.cit., p40) estimates that coal fired post-combustion power generation, via the Integrated Gasification Combined Cycle route, when compared with pulverised coal combustion generation, requires a carbon incentive price of between $20-70/tCO2.

guaranteed for sufficient periods to allow a return on capital.

2. The current high costs of CCS demonstration plants means that carbon prices are unlikely to provide an adequate incentive for a number of years. Large-scale demonstration plants will need appropriately supportive public policies if they are to be developed on a timely basis. Only when these demonstration plants have functioned for a number of years will operators gain sufficient knowledge of the cost-reduction potential to allow more confident design and deployment[10].

3. The need for significant infrastructure to transport CO2 from sources to storage sites highlights the essential role for public participation. If CCS is to be widely adopted, considerable economies will exist in the provision of a common pipeline infrastructure[11]. Its development will require permitting and approvals of right-of-way. Moreover, provisions for third party access to both pipeline infrastructure and storage sites and the terms of that access will be required if the system is to develop and be used in an optimal (i.e. aggregate low cost) fashion.

4. Identification of potential geological sinks involves search costs that might be partially socialised in a similar way to which the search costs for mineral resources are reduced by public sector geological surveys[12].

5. The storage of CO_2 in geological structures may result in conflict with the rights of other resource users, in particular with the holders of prior rights to mineral and water resources. The experience with the geological deposition of acid gas and with enhanced hydrocarbon recovery in the US suggests that the risks of cross contamination are small; nevertheless, this challenge holds the potential for costly legal action and redress. Regulations governing the location of suitable storage facilities and the requirement to monitor fluid migration would assist greatly in limiting the scope for legal challenge.

6. CCS involves the development of considerable intellectual property. Companies that hold the rights to this property might be wary about using the technology in countries where such rights are poorly protected.

The above constitute some of the commercial challenges for CCS that unless resolved will result in an investor perception of high risk for any CCS project. Should these challenges remain unaddressed high returns will likely be demanded by investors. Such an outcome could push the

[10] The IEA GHG R&D Programme believes that current CCS costs should fall by 20-40% as a result of large-scale replication and without any further technological development (personal communication).
[11] The IEA estimate that 150 000km of pipeline will be needed in the EU. Total annual pipeline costs fall rapidly with scale from about $3.50 to $0.50/tCO2/100km for an increase in the mass flow rate from 1mtCO2/yr to 20mtCO2/yr (The Future of Coal, MIT).
[12] The Australian GEODISC programme is an example of such an approach which allowed the estimation of rock storage potentials and other parameters of interest.

incentive price for many projects above likely carbon market levels for the foreseeable future.

Environmental and Safety Regulatory Challenges to CCS

CCS differs from mitigation technologies such as energy efficiency improvements that limit or avoid emissions in the sense that CO_2 is created but prevented from being emitted to the atmosphere through storage in subsurface geological formations. This gives rise to a number of regulatory and public acceptance challenges regarding safety and the long-term integrity of CO2 storage that need to be resolved if CCS is to realise its full contribution to emissions reduction.

1. CCS facilities need to be managed in a way that does not pose a threat to public safety. CO2 can pose risks to human health, as natural releases and experience in some industries, e.g. brewing, have shown. There is little reason to believe that CO2 injected into a properly selected and operated storage site would escape in a fashion to threaten human safety. There has been a long experience of CO2 transport and injection to enhance hydrocarbon recovery as well as experience with seasonal natural gas storage and acid gas disposal.
2. The transportation of CO2 from the source to the geological sink is mostly expected to be by pipeline. As with gaseous geological deposition, there is a history of continental-scale pipeline transport of CO2 as well as the transportation of other gases and liquids (eg, natural gas, synthetic organic chemicals, and high pressure steam) that pose safety risks and are routinely transported safely by pipeline[13]. CO2 pipelines should be designed and operated under similar regulatory regimes in accordance with an assessment of the risks involved.
3. CCS can represent an environmental risk through leakage, principally as a result of gradual seepage of CO2 back to the atmosphere, although local ecological risks from sudden releases could also exist[14]. The IPCC concludes that leakage rates are unlikely to exceed 1% in a thousand years[15]. Of the three large-scale CCS plants currently operating (Weyburn, In Salah, Sleipner – operating since 2000, 2004 and 1996 respectively), no leakage to date has been detected from the monitoring programmes[16].
4. CCS has the potential to conflict (and/or be prohibited under) with other regulations governing environmental protection such as landfill and groundwater protection regulations which were developed before CCS became a reality and were not designed to consider CCS. Governments intent on facilitating the implementation of CCS need to ensure that such existing regulations are appropriately amended to allow the sub surface storage of CO2[17].

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[13] In the US, 2500km of pipeline carries 40mtCO2/yr. '(A)ccident numbers reported per kilometre pipeline are very low and are comparable to those for hydrocarbon pipelines' (IPCC, op.cit., p11).

[14] Statoil have estimated the possible release as amounting to 500t CO2 arising from a worst case failure at their Sleipner Field (for example, that might result from the complete fracturing of the injection pipe). Given the pressure gradients that would be created, release of CO2 from storage sites is unlikely to be at any greater rate than was the original injection.

[15] IPCC, op.cit., p13.

[16] MIT op.cit.

[17] For instance, the EU Groundwater Directive prohibits storage in aquifers and is proposing to amend the directive 'to allow CO2 storage in aquifers permanently unsuitable for other purposes' (EU Regulation of CCS, A presentation by Scott Brocket, DG Environment, to Carbon Expo, May 2007.) This might be an unreasonably restrictive condition. An alternative formulation might follow the proposals from the Australian federal authorities to subject possible alternative possibilities to a public interest test.

Some regulations[18] are developing in a way that holds the potential to be unduly restrictive.

5. After cost, the existence of a very long term potential liability constitutes possibly the greatest challenge to the commercialization and regulation of CCS. Depending on how the issue is resolved, liability may pose significant financial hurdles. During the periods of operation and decommissioning of an injection and storage site, it is reasonable that the operating company should be held accountable for leaks from its facilities. This period of accountability might be extended for some period following facility closure and decommissioning, until reasonable assurance could be given of the stability and predicted future behaviour of the stored CO2[19]. Ultimately, in view of the very long term nature of the potential liability, management of the storage structure needs to be vested in a public body[20]. Thought needs to be given as a matter of importance to outlining the conditions governing release of the operating company from this liability. Consideration might be given by regulators to the management of and accountability for other long term liabilities, under petroleum and mining laws.

Some Recommendations

The challenges noted above will all require some attention by regulators if CCS is to be widely deployed. There are two general recommendations that are essential if progress with CCS is to be sufficiently rapid.

1. Establishment of a Regulatory Framework

Sound procedure must be established for the characterisation and selection of geological storage sites, for operation of storage facilities and for monitoring of the stored CO2. Site selection, operational and monitoring procedures need to be credible but should also be established in a manner appropriate to the risks involved and commensurate with the management of risks of similar gravity in other areas of activity. Policymakers should not impose unrealistically high standards of human and eco-system safety, or standards that are higher than those applied to analogous risks in other regulated settings. Moreover, when policymakers decide that a risk does need active management, the most cost-effective option should be preferred. So for example, the following considerations might feature in the selection and management criteria for a storage site:

- account might be taken of the impacts of not proceeding with the project and comparing these impacts with those arising from the potential for long-term gradual

[18] For instance, OSPAR restricts injection to flows that are 'overwhelmingly CO2' which has the potential to increase the costs of separating inert gases, such as nitrogen, from the flow.
[19] It is suggested by the MIT researchers that a period of 5-10 years might be sufficient. (MIT, op.cit.) However, to build confidence in the migration models a longer period would be indicated for the first generation of projects.
[20] Current proposals under the UK's Energy Bill are for the Crown Estate to assume long-term responsibility for off-shore geologically stored CO2 up to the limit of the Exclusive Economic Zone.

leakage[21];

- regulators might consider the carbon and insurance markets as offering modern risk mitigation mechanisms whereby leakage from storage structures could be either directly rectified or offset by the purchase of appropriate quantities of carbon permits on the market[22].

- monitoring and reporting procedures should be in accordance with a risk-based approach rather than any rigid standardised formulation. Assessment of monitoring procedures and results might be validated either by private sector certification bodies or directly by regulators.

The regulatory framework governing other elements of the CCS chain (capture plants and transport of CO2 by pipelines in most cases) should be in line with practice for similar industrial facilities.

2. Commissioning Large-Scale Demonstration Plants

Further development work is necessary before CCS can be fully commercialised, the regulatory requirements finalised and an appropriate incentive structure designed. Large-scale CCS demonstration plants are thereby needed urgently if CCS is to make a timely contribution to CO2 emissions reduction. Public-private partnerships are likely to be key to the successful roll-out of these demonstration plants.

Conclusions

CCS should be recognised as one of the forms of various “clean fossil fuel technology”. Other options, such as reducing fossil fuel consumption by adopting technologies to raise efficiencies in existing plants, or adding new facilities with higher generation efficiency, should be taken into consideration as well.

CCS is a promising CO2 emissions reduction technology that could play an important role in efforts to limit global warming, especially in the timeframe beyond 2030. Long-term, industrial scale experience with various CCS technologies provides confidence that CCS can be deployed safely with secure storage. However CCS is currently relatively expensive and the technological, commercial and regulatory uncertainties facing CCS must be addressed before there can be widespread deployment. Above all else, large-scale investment in CCS is unlikely to be forthcoming until a well-defined regulatory framework is established and sufficient economic

[21] This rationale was hinted at in the preamble to the recently amended OSPAR Convention where it is stated that the Commission is ‘seriously concerned by the implications for the marine environment of climate change and ocean acidification’ (Amendments to Annex II and Annex III of the Convention in relation to the Storage of Carbon Dioxide Streams in Geological Formations, Meeting of the Ospar Commission, Ostend, 25-29 June 2007).
[22] Regulators will need to account for leakage from stored CO2 in their annual emission reports to the IPPC.

incentives are available. More detailed aspects of regulation will only be determined once there is a sufficient body of operating experience and the environmental uncertainties associated with the technology are reduced. Progress in reducing these uncertainties, as well as the technological and commercial uncertainties, is unlikely to be rapid in the absence of experience gained with a number of large-scale demonstration plants that validate the various potential technical options.

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