August, 2009

# Valuation of Carbon Capture and Sequestration Under Greenhouse Gas Regulations: Carbon Capture and Sequestration as an Offsetting Activity

Elizabeth Lokey, *Boise State University*

# CCS BRIEFING PAPER # 5: Valuation of Carbon Capture and Sequestration under Greenhouse Gas Regulations Part II – CCS as an Offsetting Activity

**Elizabeth Lokey, M.S., Ph.D.**
Senior Consultant
Camco International

The background research paper was funded by the United Kingdom Strategic Programme Fund pursuant to a grant awarded to Camco International Group, Inc. during the 2008-2009 timeframe. The grant funds a series of stakeholder meetings discussing carbon capture and sequestration policy issues in Wyoming, Colorado, Utah, and Montana. This White Paper was prepared for informational purposes only as background information for these stakeholder discussions on carbon capture and sequestration. It has not received independent legal review and does not represent the perspective of the University of Colorado or Camco International Group, Inc. It should not be relied upon for legal advice and does not establish an attorney-client relationship. While potential advantages or disadvantages of different policy options may be identified, no attempt has been made to state the authors' preferences for one option over another, and no preferences should be inferred.

## Table of Contents

**Foreword**

This paper is the second paper in a two-part series covering how carbon capture and sequestration (CCS) could be valued under greenhouse gas regulation. The first paper in this series covered the implications of different types of regulation such as standards, a tax, and cap-and-trade schemes with various types of allowance allocation on CCS. This paper covers the way in which CCS could be counted as an offset and the implications thereof.

**Abstract**

Carbon capture and sequestration (CCS) could be used in the future to meet greenhouse reduction goals. When CCS is conducted by entities that are not regulated, it could be counted as an offset that is fungible in the market or sold to a voluntary market. This paper will address the complications that arise in accounting for CCS as an offset, and methodologies that exist for accounting for CCS in voluntary and compliance markets.

## I. Offsets Background

Greenhouse gas offsets are projects that reduce or absorb greenhouse gas emissions that would not have occurred in a business-as-usual situation. The number of tons of reductions that result from these projects can be counted, checked by independent third parties, and sold to entities that must meet compliance obligations. The money that can be earned through the sale of these emission reductions often provides the extra revenue necessary for the project to exist. In this way, the argument can be made that the project would not have occurred in a business-as-usual situation without the benefit of the carbon revenue. This criterion is called financial additionality, and is often required for crediting of offset projects. Also, any project that is required by a law that is enforced cannot earn carbon revenues under most recognized programs because the project would have been implemented regardless of the carbon revenues available. If a project can prove that it was not mandated by law, it passes a regulatory additionality test.[i]

Offsets have a long history in various air pollution regulations. In 1994, Pennsylvania introduced Emission Reduction Credits (ERCs) under the New Source Review and Ozone Transport Region. Project-based activities could generate fungible credits for volatile organic compounds and nitrous oxide reduction obligations in Pennsylvania's program.[ii] Now, this same principal is applied to offsets in greenhouse gas markets; a project that reduces or absorbs greenhouse gases somewhere else can generate credits that can be purchased by a regulated entity for fulfillment of their reduction targets. Offsets can be fungible in greenhouse gas markets that use a tax, cap-and-trade system, or a regulation as long as the market rules allow a reduction in a metric ton of carbon dioxide (CO2) equivalence from a qualifying project to count towards the mandatory reduction targets.

Offsets are sold in terms of CO2 equivalence in order to have only one unit of trade in the market. So, greenhouse gasses that have a higher warming potential are put in terms of their CO2 equivalence for warming purposes. For example, methane is considered by

the 2007 Intergovernmental Panel on Climate Change (IPCC) "Climate Change: The Physical Basis" report to be 25 times as potent as CO2. Therefore, reduction of one ton of methane yields 25 offsets in programs that recognize this most recent IPCC report.[iii]

The goal of offsets in this and current greenhouse gas regulation has been to reduce the cost of compliance for regulated entities. For example, if it is cheaper to capture and flare methane from animal waste than to install a more efficient boiler in-house at a power producing plant, then the owner of the power plant that needs to comply with regulation may choose to purchase offsets for compliance. It should be noted that capturing and flaring or using the natural gas must a practice that is not business-as-usual or required by law in the agricultural sector in order to be considered a qualifying offset. Also, most greenhouse gas regulation includes a supplementary clause for offsets which stipulates that compliance obligations cannot be met entirely through offsets and some in-house reductions must occur. The Kyoto Protocol stipulates that at least 50% of reductions are met domestically, and many countries have chosen even more stringent targets like the UK, which only allows 8% of its compliance obligations to be met through offsets.[iv]

Given estimates of the potential geologic storage for CO2, CCS from both regulated entities and entities outside of regulation for offset credit may comprise a large portion of the emission reductions that occur. The IPCC estimates that there is between 675-900 billion tons of CO2 storage in oil and gas reservoirs, 3-200 billion tons in unmineable coal seams, and 1,000-10,000 billion tons in deep saline formations.[v] A 2007 ICF study estimates that the lower U.S. alone has 3,375 billion tons of storage. Considering that the U.S.'s most stringent climate change legislation in 2007 called for just 7 billion tons of reductions by 2050, it is clear that CCS has the potential to make up a huge amount of the requisite reductions.[vi] However, some fear that CCS has the potential to flood the current market, lowering the price of offsets and out-competing other offset activities. All of the registered offsets under the Kyoto Protocol's Clean Development Mechanism, the largest offset program worldwide, have only been issued 267 million tons of CO2 reductions.[vii]

Before CCS is at danger of flooding the offset market, technical, as well as regulatory hurdles, must be overcome. Only then does it have the potential to allow future carbon markets to operate more efficiently and make reductions for the cheapest possible price. While owners of other offset projects are wary of CCS for its possible implications, industries like electrical power producers, natural gas processers, fertilizer manufacturers, and ammonia producers, who could participate in CCS, are hopeful about obtaining these carbon credits because of their economic value.

The compliance carbon offsets track the price of emission permits (European Union Allowances-EUAs) in the EU's European Trading Scheme and can be sold for about 30% less than the EUA price at any given time. Carbon markets, like other markets, fluctuate and in July of 2008, an offset in this market reached a high of $24. By February of 2009, an offset was only worth $8.[viii] Whether or not this price would provide a steady enough price signal to incentivize the development of CCS can be debated.

The exact way in which CCS is valued, either as an offset or as tons not emitted from a regulated entity, has a large bearing on the role it will play in future markets. Therefore, before one can ascertain whether or not the price of CO2 will be high enough to incentivize CCS, whether offsets from CCS will dominate an offset market, and whether regulated entities will be limited in their use of these offsets, it is essential to consider from which sectors CCS offsets would be eligible. The next section considers this point.

## II. Offsets in Various Industries

*a. Regulated Entities*

Australia and the EU have determined that CCS will reduce an emitter's greenhouse gas liabilities and count as emissions that are simply "not emitted" in their cap-and-trade schemes.[ix] However, CCS from regulated industries could alternatively be considered an offset activity. Australia considered this form of valuation during the creation of its greenhouse gas legislation. In this situation, emitters that employ CCS would quantify the emissions coming out of their stacks even if these stack emissions are immediately piped to sequestration sites. The amount of emissions that leave the stack at the facility would be used for baseline accounting and inventory purposes. Then, as the CO2 is sequestered underground, the regulated entity would earn offsets for this activity. These offsets could then be counted against the CO2 they are emitting or sold to other market participants.[x]

No countries have thus far adopted this choice of carbon accounting for CCS because it creates a negative image for a polluting entity, as its emissions are shown to be much higher than they would be without CCS. This form of carbon accounting also adds a level of perhaps unnecessary complexity to the market as regulators must inventory emissions, generate offsets, and then track the trade of offsets.[xi]

*d. Other Industries*

The vast majority of federal cap-and-trade proposals and nascent U.S. regional and state regimes propose to instigate a carbon market that would cover large point source emitters. Many sectors may not be covered by a cap-and-trade for political reasons or because monitoring and reporting may be difficult or costly. For some of these sectors like transport with non-point source pollution, CCS may never be a realistic CO2 reduction option. However, there are many other industrial sectors that could engage in geologic CCS but may not be regulated in the first phase of the market. For instance, the Regional Greenhouse Gas Initiative, which covers 10 states in the Northeastern U.S., only regulates power producers in its first phase from 2009-2012.[xii] If a national scheme is designed in a similar way that only covers power producers, then some major producers of CO2 that may not initially be regulated include oil and gas processors, fertilizer plants, and ethanol and ammonia producers. For these industries, which have a nearly pure stream of CO2 emissions from their plants, investment in the most expensive portion of CCS, the capture and separation technology, may not be required. CCS may be

financially viable for these producers, especially if a CO2 pipeline that they can use runs close to their operations. Other emitters like oil and gas processing facilities may also be candidates for CCS, especially if co-contaminants like hydrogen sulfide can be sequestered with the CO2 as they are at 43 sites in British Columbia and Alberta, Canada.[xiii]

None of the existing or proposed greenhouse gas markets have provided provisions for offsets generated by CCS activities in industries outside of the cap or regulated environment. The subsequent section will describe how efforts to undertake CCS before an industry is regulated should be counted as offsets and why future regulation should explicitly address offsets in unregulated industries.

## III. Early Action by Regulated Entities

Large point-source CO2 emitters that are not required to account for and reduce their emissions in the first phase of the market, but most likely will be required to in subsequent stages of the market have the potential to benefit from CCS in two ways: through counting the sequestration of tons as "early offsets" or as "early action." Early offsets are offsets generated by a sector that will eventually be regulated and have the future stream of offsets from a given activity disappear as the sector will no longer be eligible for generation of offsets but instead required to make reductions. Early action is when emitters that are initially not covered by the cap or other regulation make reductions before they are regulated and receive credit for these actions taken in a future market. This type of action can also be taken and documented by regulated entities in advance of a cap-and-trade program commencing.

It is important to encourage early action for sectors that are initially not covered by the market to incentivize reductions and ensure that facilities are not penalized for reducing CO2 emissions in advance of regulations. A facility would be penalized by early action if it received fewer allowances when it was eventually covered by the cap or other regulation because of the early action measures it put in place ahead of the regulation. Early action is often mentioned in proposed greenhouse gas legislation, but usually does not mention CCS as an approved mitigation strategy that would earn early action recognition.[xiv]

Because early action has not been recognized in all climate change legislation, especially for industries that will not be the first ones capped, there may be a perverse incentive for emitters either to do nothing to reduce their emissions or to increase their emissions until there is regulatory certainty about early action. If these emitters increase their emissions, then there is the possibility that they may earn more allowances in a cap-and-trade system where emissions are freely distributed based on the historical emissions of emitters.[xv]

Most measures to implement early action through CCS may be used strictly in the accounting of a company's emissions. In this scenario, the company assumes that it will be regulated in the future and that emissions that are sequestered through CCS will be credited towards the emission permits of allowances that it is either given or does not have to purchase in an auction. However, whether or not this activity is recognized depends on the details of the greenhouse gas regulation. Generally, a baseline year is selected and any early action activities taken before this year will not be recognized.

The further in the future a given sector is regulated, the greater the chance that this baseline year will be in the future.

*a. Early Offsets*

If a non-regulated entity does not think that it will be regulated in the near-term or even perhaps at all, it may decide that instead of simply reporting its reductions in emissions due to CCS, it will earn offsets for each metric ton sequestered and forego any early action crediting it would receive when it was actually covered by the regulation. In this way, the offsets generated are referred to as "early offsets" because they are offsets that can be generated only up to the point when that entity is regulated. For example, if an ammonia producer that is outside of the greenhouse gas regulation implements CCS in 2010 and early action for ammonia producers is recognized only for activities completed during the years of 2012 and beyond in future legislation, then the ammonia producer that engaged in CCS fails to benefit from these activities except through the offsets it generated before the market began. In fact, if offsets are not generated in this situation, the CCS activities may even hurt the ammonia as its baseline of emissions would be quite low or nothing at all when its industry is capped. In an allocation system where allowances are given to emitters based on historical emissions, the ammonia producer's competitors would receive allowances that have value while it would not.

## IV. Complications with Earning Carbon Credits for CCS

Despite the potential for deriving offsets from CCS for electrical and non-electrical sectors, there are many complications to earning credit for CCS activities as offsets or as allowances. For many of these reasons, CCS has not been approved by the UNFCCC for use in the Kyoto Protocol's Clean Development Mechanism (CDM). Participants of the Kyoto Protocol's Conference of Parties in 2008 feared that incorporation of CCS into the CDM would make developing countries a testing ground for CCS trials. Using an immature technology in developing countries could lead to health violations and abuse since environmental and industry standards are usually more lax in developing nations. Also, using CCS often causes emerging economies to rely on finite fossil fuel resources like coal that incur extraction externalities like land disturbance. Finally, the technical complexities of CCS have not yet been proven to a commercial level in developed countries. Therefore, this technology could have unforeseen problems when implemented in developing countries [xvi] And, as previously mentioned, other critics of having CCS in the CDM claim that it could flood the market with offsets, causing all other emission reduction projects to lose value and be overshadowed by CCS. This reliance on CCS projects could cause an unequal distribution of projects based on where there are opportunities to implement CCS. Also, the issue of how to provide long-term monitoring and liability for these projects was raised. Therefore, many oppose CCS implementation on the grounds that it is the wrong type of energy future for developing nations.[xvii]

Despite the fact that CCS has not yet been approved for the CDM, two CDM projects in Malaysia and Vietnam have submitted methodologies for CCS projects under the CDM, and Shell and the International Energy Agency (IEA) have created proposed methodologies for CCS.[xviii] Also, the United Nations Framework Convention on Climate Change (UNFCCC) has authored several documents considering some of the challenging issues related to quantifying emission reductions from CCS. The obstacles identified in these documents are methodological, technical, legal, and policy-related. Some of these challenges include the energy penalty associated with CCS, physical

leakage, permanence of storage, long-term liability and monitoring, understanding and predicting sub-surface CO2 behavior and preparing remediation options, and the definition of a project boundary.[xix]

*a. Energy Penalty*

Because separating CO2 from a stack, transporting it, and injecting it requires significant inputs of energy, a metric ton of CO2 stored through CCS is not equal to a metric ton of CO2 mitigated through other methods. The energy for CCS is estimated to be between ~11-40% of the fuel required for a fixed output of work.[xx] Because of this energy penalty associated with CCS, credit for CCS activities must take into account the energy and emission intensity of the steps necessary to sequester the CO2. Creating a standardized equation to account for this energy penalty is difficult because of the variety of locations such as fertilizer plants, power plants, and ethanol refineries from which CO2 can be derived, and the distinct separation technology and transport requirements necessary to conduct CCS for each of these situations.[xxi]

*b. Physical Leakage*

From a carbon credit generation standpoint, the issue of physical leakage from the site would present an obvious complication for the allocation of carbon credits. If the site cannot hold the carbon expected, then it should not receive carbon credits. How then, should the carbon credits be discounted to accurately reflect the amount of CO2 that escapes, and how can one predict the amount of leakage over hundreds or thousands of years? One option to resolve this problem would be for future allowances given to emitters to be taken out of the overall pool of allowances. However, how to allocate discounted credits is unclear since leakage could occur over hundreds or thousands of years.

The issue of the physical plume size has been flagged by the UNFCCC and is an important one when considering how to allocate the carbon credits.[xxii] Since science has not yet defined with 100% accuracy the extent of plume migration, it is possible that the injected CO2 could invade pore space that belongs to others such as landowners, mineral rights owners, or the state/federal government. The owners of this other pore space would probably own the right to the carbon credits for the CO2 stored in their property. The patchwork of ownership rights in reservoirs could cause a complicated allocation of carbon credits to owners or involve payouts to these entities for the right to inject in their land. For instance, injected gas in one reservoir diminishes the ability of the injector's neighbors to inject and hence, lose the opportunity for carbon credits.[xxiii] In this case, would the neighbors earn a portion of the carbon credits that is equal to their reduced capacity to inject? It would probably be impossible to determine this amount with complete scientific certainty, and doing so may lead to complicated litigation between neighbors as each tries to maximize their carbon credit portion.

*c. Crediting Lifetime*

Another issue of concern for carbon credit generation is the lifetime of the project. A typical CDM project has a lifetime of up to 21 years after three crediting periods,[1] and generates CERs which have expiration dates and which need to be replaced after they expire. However, such short crediting periods do not accurately reflect the near

[1] Forestry CDM projects are unique in that they have a crediting period of either 30 years or two successive periods of 20 years.

permanent sequestration of CO2 and may not provide a sufficient financial incentive to employ CCS.[xxiv] The Intergovernmental Panel on Climate Change has high expectations for the permanence of geologically sequestered CO2 saying "the fraction retained in appropriately selected and managed geological reservoirs is likely to exceed 99% over 1000 years."[xxv] However, the key consideration in this assumption is that the site where the CO2 is injected is appropriately selected and managed. This assumption is, of course, subjective and depends on the regulatory structure in place. If the sequestration is truly permanent as the UNFCCC predicts, then perhaps a longer time horizon for CCS could be proposed. The idea of issuing these carbon credits as geologic sequestration units (GSUs) has been proposed.[xxvi] It is possible that these GSU offsets would have an implicitly lower value than other, less risky forms of emission offsets. However, introducing credits that are not fully fungible and must be sold at a discount into the global trading schemes would greatly complicate the markets and tracking systems.

## V. Existing Methodologies for CCS as Offsets

Despite all of the complexities inherent in awarding carbon credits for CCS, several programs described in this section have designed methodologies which give carbon credits for geologically sequestered CO2. It is important to note that no methodology exists for CCS in its purest form, without the ancillary benefits of acid gas injection or enhanced extraction of a resource such as enhanced oil recovery (EOR) or enhanced coalbed methane recovery (ECBM).

Injecting CO2 into these reservoirs forces more of the commodity out of the ground. Some of the CO2 returns to the surface, is separated from the oil or gas, and then reinjected to force more of the oil and gas. During this process, about 50% of the injected CO2 stays embedded in underground pore space.[xxvii] During natural gas extraction, hydrogen sulfide (H2S) and CO2 is often found in the same reservoirs as the natural gas. During natural gas processing, this H2S and CO2 must be stripped from the natural gas and disposed of. The H2S can either be remediated at the ground level or injected, along with the CO2, into underground reservoirs.[xxviii] This section will discuss the carbon crediting that occurs for these EOR, ECBM recovery, and acid gas injection activities.

### *a. Blue Source*

A carbon consultancy called Blue Source developed a methodology for the creation of carbon credits in voluntary markets for EOR activities that use anthropogenic CO2 from industrial processes that would have been off-gassed. [xxix] In this way, the CO2 from natural gas processing used for EOR is replacing CO2 from underground reservoirs that would have been used in a business-as-usual situation. The companies like PetroSource and Merit Energy using this protocol are large processors and most likely will be regulated at some stage in a future compliance regime. They may have implemented the projects in part to reduce their greenhouse gas liabilities, hoping that they may earn early action credit in addition to the offset credit they are now earning for their sequestration activities.

As of May 2009, the only project developer to use this methodology is Blue Source. In the US, Blue Source used the Environmental Resources Trust's GHG Registry which became the American Carbon Registry as the standard and registry, which accepted the methodology, show documentation related to the activity, and handles the issuance

and tracking of credits from the project. Verification for Blue Source projects is done by firms such as Ruby Canyon Engineering, URS Corporation, and First Environment.[xxx] Some of Blue Source's customers include Dell, Delta, AEP, Google, Pacific Gas & Electric, Yahoo, and Nike. As of November 2008, 10 million tons of voluntary or verified emission reductions (VERs) had been created and sold from these projects.[xxxi]

*b. Alberta Environment*

Alberta Environment of Canada worked closely with Blue Source to develop EOR methodologies, which are similar to the one described in the section above. These methodologies are used for offset crediting in the Alberta intensity-based greenhouse gas system. In total, there are three CCS-related methodologies that are eligible for use in Alberta. Two of these methodologies allow offsets to be generated from EOR projects that use CO2 that would have otherwise been vented into the atmosphere. One of these takes into account EOR that creates emissions as CO2 is separated from other waste gas streams while the other does not.[xxxii] A third CCS methodology involves geologic sequestration of H2S, CO2, and other airborne contaminants from natural gas processing facilities. Industries in Canada that use any of these methodologies are able to sell the offsets from these projects to entities that need them for compliance purposes.[xxxiii] Offsets earned for these activities are registered with the Canadian Standards Association CleanProject Registry and Alberta Emissions Offset Registry.

If a company is regulated within the Canadian market because it emits more than 100,000 tons of CO2 equivalence, then it can engage in these EOR and acid gas activities and earn credit for doing so if the company surpasses its reduction goals. This credit is commoditized into Emission Performance Credits (EPCs) that are fungible among regulated entities. Two companies have earned EPCs for acid gas injection activities, and one has earned offsets for it.[xxxiv]

*c. Oklahoma Conservation Commission*

During the summer of 2008, the Oklahoma Conservation Commission drafted a methodology for verifying carbon sequestered during EOR activities in the State of Oklahoma. The goals of this verification program include assuring Oklahoma offsets meet a standard, encouraging the capture of anthropogenic CO2, and providing a mechanism for carbon sequestered as a result of EOR to be recognized as a credible offset. A co-benefit of the program is that it will likely encourage more EOR activities in the state. The program rules are still in development, and many details of the program will be finalized in the next year. Like the Blue Source methodology described above, EOR projects that use anthropogenic CO2 from the stack of natural gas processors and other industrial activities that would have otherwise been off-gassed are eligible for verification. Since EOR involves the injection, extraction, and reinjection of a known amount of CO2 several times, a mass balance equation that takes into account the total CO2 that is injected and not recovered can be used to quantify and verify annually the amount of CO2 to be counted as offsets. Projects must follow applicable EPA Underground Injection Control Program's rules for permitting and monitoring. In Oklahoma, ex-post verification of these projects will occur by the state or state-approved verifiers. The verified credits will be posted on a state-created offset registry with the sale of credits solely at the discretion of the project operator. At this time the program is not affiliated with other, recognized greenhouse gas programs like the Voluntary Carbon Standard, the Chicago Climate Exchange, the Gold Standard, and the California Climate Action Reserve.[xxxv]

## VI. Conclusion

Given that the Intergovernmental Panel on Climate Change estimates for the potential geologic storage of CO2, CCS has the potential to play a huge role in climate change mitigation.[xxxvi] CCS will certainly have a role in helping regulated entities meet their reduction targets, but may also be instrumental in helping facilities that are initially or permanently not covered by regulation reduce global levels of greenhouse gases. Allowing tons sequestered from entities outside of regulation to count towards reduction targets in the market would make CCS a valid form of an offsetting activity.

However, there is not yet certainty that sectors outside of regulation will earn credit for sequestration activities, and there is an urgent need to clarify which sectors can earn early action credit for CCS activities to incentivize this practice among electric power producers and other industrial sectors that may implement CCS before the regulation or fall outside of the regulation once it has begun. Without these provisions, there is a perverse incentive for emitters to do nothing to reduce their emissions in an attempt to avoid jeopardizing the allocation of allowances they may receive. No countries have fully designed these early action rules. In the absence of such rules, entities that may in the future be regulated may choose to either not implement CCS or earn early offsets for CCS.

Most compliance and voluntary offset programs have not yet adopted CCS as a valid offsetting activity because of the inherent challenges in accurately counting offsets from CCS. These groups point to difficulties in accounting for the CO2 that may leak from the reservoir in future years, considering complexities for the baseline calculation, deciding how long the life of the issued offset should be, determining who is liable for the injected gas years in the future when the present institutions may be non-existent, and assigning carbon credit ownership. And, CCS, in the opinion of the UNFCCC, is not yet ripe to be counted as offsets derived from developing countries because of its unproven status.

However, some methodologies that do offer credits for these activities have been developed by the Conservation Commission of Oklahoma, Blue Source, and Alberta Environment. These projects may help push the market for CCS, and the methodologies created for these projects may serve as the beginning of a template for future CCS offset protocols, as future greenhouse gas regulators find they must turn to CCS to mitigate climate change.

---

[i] Ramseur, J.L., *The Role of Offsets in a Greenhouse Gas Emissions Cap-and-Trade Program: Potential Benefits and Concerns.* Congressional Research Service, April 4, 2008.

[ii] Law Offices of Harry F. Klodowski, "Ozone Offset Trading in Pennsylvania," Paper presented at the Annual Meeting of the Air and Waste Management Association in June 1996.

[iii] Forster, P., V. Ramaswamy, P. Artaxo, T. Berntsen, R. Betts, D.W. Fahey, J. Haywood, J. Lean, D.C. Lowe, G. Myhre, J. Nganga, R. Prinn, G. Raga, M. Schulz and R. Van Dorland, 2007: 'Changes in Atmospheric Constituents and in Radiative Forcing.' *In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate*
*Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA

[iv] Diamont, A. The Key Role of Greenhouse Gas Emissions Offsets in Evolving GHG Cap and Trade Programs. in RMEL: Carbon Issues and Strategies. April 17, 2008. Denver, Colorado.

[v] Working Group III of the Intergovernmental Panel on Climate Change (IPCC), "Technical Summary" in Carbon Capture and Sequestration, IPCC Special Report, 2005.
[vi] ICF, "Developing a Pipeline Infrastructure for CO2 Capture and Storage: Issues and Challenges," Prepared for INGAA Foundation, February 2009.
[vii] UNFCCC, "Clean Development Mechanism," Accessed on March 23, 2009, available at http://cdm.unfccc.int/index.html
[viii] "Point Carbon Historical CER OTC Assessment," Point Carbon, March 23, 2009.
[ix] Australia Department of Climate Change, "Carbon Reduction Scheme Green Paper," July 2008 and European Parliament and the Council, "Amendment 3: Compromise Amendments 1-25," Directive 2003/87/EC May 10, 2008.
[x] Australia Department of Climate Change, "Carbon Reduction Scheme Green Paper," July 2008.
[xi] Australia Department of Climate Change, "Carbon Reduction Scheme Green Paper," July 2008.
[xii] "Carbon Market North America," Point Carbon, November 21, 2008.
[xiii] "Quantification Protocol for Acid Gas Injection," Alberta Environment, Version 1, May 2008 and Sarah Forbes, Kate Robertson, Jette Findsen, and Steve Messner, *International Carbon Capture and Storage Projects Overcoming Legal Barriers,* 24 (DOE/NETL-2006/1236, 2006), *available at* http://www.netl.doe.gov/energy-analyses/pubs/ccsregulatorypaperfinalreport.pdf
[xiv] California Environmental Protection Agency, Air Resources Board, "Early Action Items," Accessed on December 15, 2008, http://www.arb.ca.gov/cc/ccea/ccea.htm.
[xv] Michael Grubb and Karsten Neuhoff "Allocation and competitiveness in the EU emissions trading scheme: policy overview," Cambridge Working Papers in Economics 0645, June 2006.
[xvi] Tom Young, "UN Blocks Carbon Capture's Entry to CDM Offset Scheme," Business Green, December 11, 2008.
[xvii] Tim Dixon, "Update from Poznan: UNFCCC SBSTA 29 and COP 14 and CMP 4," Carbon Capture and Storage Association, December 15, 2008.
[xviii] Julian Richardson, "CCS and its future in CDM," CDM Investment Newsletter, Number 1, 2009 and International Energy Agency, *ERM Carbon Dioxide Capture and Storage in the Clean Development Mechanism,* International Energy Agency Greenhouse Gas R&D Programme, April 2007 and "Clean Development Mechanism Proposed New Baseline and Monitoring 03.1 for CCS," Proposed by Shell.
[xix] UNFCCC Secretariat, *Synthesis of views on issues relevant to the consideration of carbon dioxide capture and storage in geological formations as clean development mechanism project activities*, April 9, 2008.
[xx] House, K.Z., Harvey, C.F., Aziz, M. J., & Scrag, D.P., "The energy penalty of post-combustion CO2 capture and storage and its implications for retrofitting the U.S. installed base," *Energy and Environmental Science*, advance article, published online January 23, 2009.
[xxi] *ERM Carbon Dioxide Capture and Storage in the Clean Development Mechanism,* International Energy Agency Greenhouse Gas R&D Programme, April 2007.
[xxii] UNFCCC Secretariat, *Synthesis of views on issues relevant to the consideration of carbon dioxide capture and storage in geological formations as clean development mechanism project activities*, April 9, 2008.
[xxiii] Mentioned by Dwight Peters, "CO2 Sequestration Needs: Technology and Otherwise," Schlumberger Carbon Services, Presented at the Big Sky Regional Partnership Annual Meeting, October 28, 2008 in Spokane, Washington.
[xxiv] R Stuart Haszeldine, et al. "Regulation for CCS beneath the UK offshore and onshore: deep geological storage and sequestration of CO2," International Risk Governance Council, April 2007.
[xxv] Paul Freund, et al. "Carbon Dioxide Capture and Storage: Chapter 1 Introduction," Intergovernmental Panel on Climate Change, 2005.
[xxvi] Shalini Vajjhala, Jenny Gode, and AsbjØrn Torvanger, "An International Regulatory Framework for Carbon Capture and Storage," Resources for the Future, July 2007.
[xxvii] "Weyburn Enhanced Oil Recovery Project," International Energy Agency Greenhouse Gas Research and Development Programme, http://www.co2captureandstorage.info/project_specific.php?project_id=70
[xxviii] "Acid Gas Injection Proves Economic for West Texas Gas Plant," Oil and Gas Journal, Volume 98, Issue 21, May 22, 2000.
[xxix] Blue source, *Blue Source's Greenhouse Gas Emission Reduction Protocol for PetroSource's Capture of Vent-Stack CO2 at Pikes Peak in Combination with Enhanced Oil Recovery Operations*, November 2007.
[xxx] "Strategic Alliances," Blue Source, Accessed on December 16, 2008, http://www.ghgworks.com/2b-alliances.html.
[xxxi] Katie Dunn, "AES – Carbon Offset Providers Coalition (COPC) Offset Hill Briefing," Blue Source, March 26, 2008, http://www.carbonoffsetproviders.org/resources/Dunn+BlueSource+$282$29.pdf.
[xxxii] "Quantification Protocol for Enhanced Oil Recovery- Streamlined," Alberta Environment, Version 1, October 2007 and "Quantification Protocol for Enhanced Oil Recovery," Alberta Environment, Version 1, October 2007.
[xxxiii] "Quantification Protocol for Acid Gas Injection," Alberta Environment, Version 1, May 2008.
[xxxiv] Bob Savage, Alberta Environment, Personal Interview, December 17, 2008.
[xxxv] Oklahoma Conservation Commission, *Carbon Sequestration Certification Program – Emergency Rules*, May 27, 2008 and Stacy Hansen, Director, Oklahoma Carbon Sequestration Verification Program, Personal Interview, December 17, 2008.
[xxxvi] Working Group III of the Intergovernmental Panel on Climate Change (IPCC), "Technical Summary" in Carbon Capture and Sequestration, IPCC Special Report, 2005.