Estimating and Reporting GHG Emission Reductions From CO_2 Capture and Storage Activities

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By:

Jette Findsen and Christina Davies
Science Applications International Corporation (SAIC)

Sarah Forbes
National Energy Technology Laboratory (NETL)

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1.0 Introduction

Over the past decade, the capture and geologic storage of carbon dioxide (CO_2) has gained increasing attention as a viable greenhouse gas (GHG) mitigation option. Policies to encourage research and implementation of capture and storage projects have been introduced at national and local levels, CO_2 capture and storage activities have been reported to national GHG registries, and GHG emission reductions from CO_2 capture and storage have been traded on the emerging GHG market. In February 2003 the Intergovernmental Panel on Climate Change (IPCC) announced that it will prepare a Special Report on carbon capture and storage citing the very high GHG mitigation potential of this CO_2 management technology.[1] In addition, the World Resources Institute (WRI) and the World Business Council on Sustainable Development (WBCSD) is convening a multi-stakeholder partnership of businesses, NGOs, governments and others to develop standards and guidance for quantifying the GHG emissions/removals resulting from GHG mitigation projects, including some geologic sequestration activities.

The increased use of CO_2 capture and geologic storage in national and international climate change systems has created a growing need for methodologies to account for the emission benefits of geologic sequestration.[2] This paper will describe the capture and storage activities that have been reported within existing GHG emissions trading, voluntary reporting, and inventory systems. It will discuss current GHG emissions accounting guidance relevant to geologic sequestration, and will highlight some of the major emissions accounting issues related to the reporting of CO_2 capture and storage activities.

2.0 Capture and Storage Activities in the GHG Market

Recent analyses indicate that between 1996 and 2002 at least 280 transactions had been completed representing 335 million metric tons of CO_2 equivalent.[3] A small but growing share of these transactions has been based on geologic sequestration, which represented about three percent of the emission reductions traded between 2001 and 2002.[4] Other project types include fuel-switching, energy efficiency, renewables, industrial, transportation, landfill gas management, and land use change and forestry. Table 1 provides an overview of three sample CO_2 capture and storage transactions. Each of these trades was based on capturing waste CO_2 at industrial facilities and using this CO_2 for enhanced oil recovery (EOR) as replacement for naturally occurring CO_2. For example, one of these trades, announced in February 2002 between Ontario Power Generation and Blue Source, involved a forward purchase of 6 million tonnes of CO_2 equivalent resulting from EOR projects in Texas, Wyoming, and Mississippi using CO_2 that would otherwise be vented by natural gas processing plants. In each case, one company generates the the emission reductions by buying captured CO_2 from waste processes at nearby industrial firms and transporting and selling it for EOR in oil fields in Texas, Wyoming, or Mississippi. The buyers were

[1] Intergovernmental Panel on Climate Change (IPCC). "Scoping Paper: IPCC Special Report on Carbon Dioxide Capture and Storage." Draft, November 29, 2002/TSU WG III.
[2] In this paper, geologic sequestration refers to the capture and long-term storage of GHGs within geological oil and gas reservoirs, deep saline aquifers, and deep coal seam structures. The paper considers enhanced resource recovery through the injection of CO_2 sourced from industry activities such as power generation and oil and gas processing and production. Deep ocean fertilization, iron fertilization, and carbon sequestration in forestry and other vegetation are not addressed.
[3] Franck Lecocq and Karan Capoor. "State and Trends of the Carbon Market." Presentation prepared for PCF*plus* Research. October 2002; and "ViewPoint: The UK ETS quieting down", *Europe Weekly* PointCarbon, February 21, 2003. www.pointcarbon.com
[4] Accurate information regarding the size, number, and value of transactions in the emerging GHG market is difficult to obtain due to privacy concerns of many companies engaged in emissions trading.

companies seeking to offset some of their emissions, and in the case of the trade between Blue Source and the utility ELSAM in Denmark, the trade was used to meet a mandatory GHG emission reduction target.

Table 1. Sample CO_2 Capture and Storage Transactions

Program	Activity	Seller	Buyer	Volume Traded (metric tons CO_2)
Registered with Clean Air Canada	Forward trade: Industrial waste CO_2 for EOR in Texas, Wyoming, and Mississippi, delivered between 2001 to 2007	Petro Source/ Blue Source	Ontario Power Generation	Up to 6,000,000
Denmark, Emissions Trading System	Industrial waste CO_2 for EOR projects in Texas	Petro Source/ Blue Source	ELSAM, Denmark	N/A
N/A	Forward trade: Industrial waste CO_2 for EOR in Texas and Wyoming, delivered between 2002 and 2012	Petro Source/ CO2E.com	Greenhouse Emissions Management Consortium (GEMCo) in Canada	600,000

The value of the recorded transactions in geologic sequestration is not publicly available. However, current market surveys of past GHG transactions indicate that past trades have ranged between US$ 1 to 2 in the North American market and US$ 2 to 4 in the Danish market, where the three known trades in CO_2 capture and storage took place. Hence, the price of the three capture and storage transactions must have ranged between US$1 to 4. Table 2 provides an overview of transaction values in major GHG markets.

Over the past couple of years, the focus in the market has shifted from North America toward Europe, largely because of the U.S. decision not to ratify the Kyoto Protocol, the startup of the United Kingdom (UK) emissions trading system, and the proposed directive for a European-wide trading scheme. In 1996, 100 percent of GHG emission trades took place in the United States; in 2002, more than one-half of the 150 GHG transactions negotiated took place in Europe.[5] Emissions trading activity in the United States could increase, however, with the expected opening of the Chicago Climate Exchange (CCX) in spring 2003. CCX is a voluntary cap and trade program. Participating members will be able to buy and sell GHG credits to assist in achieving their emission reduction commitments.

Table 2. GHG Transaction Values[6,7,8]

GHG Trading System	Transaction Price (US$/Metric Ton CO_2E)
UK, Emissions Trading	7-18
UK, Auction	23
ERUPT/CERUPT (Dutch Government)	4-5
World Bank PCF	3-4
Denmark, Emissions Trading	2-4
North America, Private Trades	1-2
Other	0.5-5

The higher value of transactions in GHG systems with detailed guidance for emission accounting and project design, such as the UK emissions trading system, the Dutch ERUPT/CERUPT program, and the World Bank Prototype Carbon Fund (PCF), indicate that emission reduction projects that use consistent accounting guidelines will be traded at a higher premium. Moreover, independent verification of the traded emission reductions also increases transaction value significantly. These trends would also apply to

[5] Franck Lecocq and Karan Capoor. "State and Trends of the Carbon Market." Presentation prepared for PCF*plus* Research. October 2002.
[6] Atle C. Christiansen. "Overview of European Emissions Trading Programs." Presentation at the EMA 6th Annual Fall Meeting & International Conference. September 29-October 1, 2002. Toronto, Canada.
[7] Franck Lecocq and Karan Capoor. October 2002.
[8] "ViewPoint: The UK ETS quieting down", *Europe Weekly* PointCarbon, February 21, 2003. www.pointcarbon.com

transactions based on CO_2 capture and storage. However, at this point, none of the existing GHG offset projects or trading programs have developed any guidance on emissions accounting and project design that directly addresses geologic sequestration.

Table 3. Voluntary Reporting of CO_2 Capture and Storage Activities

Program	Activity	Reporter	Average Annual Reduction (metric tons CO_2)
US DOE 1605(b) Voluntary Reporting of GHG Program	Waste CO_2 captured from the LaBarge natural gas processing plant owned by Exxon-Mobil is used for EOR in the Rangely Weber Sand Unit operated by ChevronTexaco.[9]	Rangely Weber Sand Unit	19,054,687
US DOE 1605(b) Voluntary Reporting of GHG Program	CO_2 from a natural gas compression engine at the TXU Ranger facility was captured and injected by TXU into an old well field to improve oil/gas recovery.[10]	TXU	6,812
Canada's Climate Change Voluntary Challenge and Registry (VCR)	CO_2 captured from the Nova-owned Joffre Ethylene-Polyethylene plant in Alberta is used for an EOR project operated by an oil producer in the area.[11]	Nova Chemicals	N/A
Canada's Climate Change Voluntary Challenge and Registry (VCR)	Captured waste CO_2 from industrial vent stacks is purchased and aggregated by Petro Source and transported and sold for EOR in Texas and Wyoming. Emission reductions will be delivered to EPCOR between 2008 and 2012.[12]	EPCOR Utilities Inc. (Part of GEMPCo agreement with Petro Source)	180,000
GHG Emission Reduction Trading Pilot (GERT) – Canada	Re-injection of captured CO_2 (and hydrogen sulphide) from Westcoast Gas Services' Jedney natural gas processing plant into a depleted gas reservoir operated by Westcoast.[13]	Westcoast Gas Services, Inc.	17,000
Clean Air Canada	Captured waste CO_2 from industrial vent stacks are purchased by Petro Source and transported and sold for EOR in Mississippi, Texas and Wyoming.[14]	Petro Source Blue Source LLC	2,240,000
AIJ Pilot Phase of UNFCCC	Fugitive CO_2 during fermentation process in a Croatian brewery is captured and used for carbonation during beer production.[15]	Interbrew, Belgium	50,250

3.0 Voluntary Reporting of Capture and Storage

CO_2 capture and storage projects have been reported to several national GHG reduction and reporting programs, which have been set up to encourage voluntary GHG emission reduction activities by the public and private sector. As indicated in Table 3, most of the relevant CO_2 capture and storage activities were reported to voluntary GHG programs in the U.S. and Canada, however, one project was also developed under the Activities Implemented Jointly Pilot Phase of the U.N. Framework Convention on

[9] Energy Information Administration. Voluntary Reporting of Greenhouse Gases, web site: http://www.eia.doe.gov/oiaf/1605/current.html

[10] TXU sold the Ranger Facility in 2000 and is no longer reporting any reductions from this project.

[11] NOVA Chemicals, "2002 Submission to Canada's Climate Change Voluntary Challenge and Registry: Managing Greenhouse Gas Emissions," October 2002.

[12] EPCOR Utilities Inc., "Voluntary Action Plan Progress Report 2001," Updated October 2002.

[13] GERT Quantification Guideline: Acid Gas Re-Injection. June 10, 2002; and "Westcoast Gas Services Jedney and Highway Gas Plants Operational" Westcoast Energy Press Release. July 24, 1997. web site: www.westcoastenergy.com/newsreleases/bak/1997jul24_0.html

[14] URS Corporation. "Emission Reduction Credit (ERC) Creation Report for Petro Source's Capture of Vent-Stack CO_2 in Combination with Enhanced Oil Recovery Operations." March, 2001.

[15] Report Submitted for Approval By the Belgian and Croatian National Authorities on Activities Implemented Jointly. July 1998. web site: unfccc.int/program/coop/aij/aijproj.html

Climate Change (UNFCCC). Geologic sequestration is not included in the project-based mechanisms of the Kyoto Protocol.

3.1 Capture and Storage Projects Reported to the 1605(b) Voluntary Reporting of GHGs Program

Two geologic sequestration projects have been reported under the existing 1605(b) Voluntary Reporting of Greenhouse Gases Program of the U.S. Department of Energy. Both reported projects use waste CO_2 captured from a gas processing plant for EOR applications and in both cases the owners of the EOR fields reported the emission reductions. As part of the first project, CO_2 captured from natural gas production at the La Barge processing plant (western Green River Basin, Wyoming) is piped to Rangely Field in Colorado and used for EOR. Natural gas at La Barge contains a high percentage (approximately 70 percent) of CO_2. The operator of the Rangely field, known as the Rangely Weber Sand Unit (RSWU), has reported an indirect reduction equal to the amount of CO_2 purchased minus the CO_2 flared with the rationale that CO_2 captured at La Barge would otherwise be vented to the atmosphere. Over the 1986 to 1999 time period, RSWU reported an average annual reduction of 1,247 metric tonnes of CO_2. As part of the second project, TXU reported reductions from a TXU EOR operation that employed waste CO_2 from the TXU Ranger Facility for the use of enhanced oil and gas recovery in an old well field. The average annual reduction reported during the TXU project life (1996-1999) was 1,700 metric tonnes of CO_2. The TXU project description does not address what would have happened in the absence of the CO_2 capture and storage activity.

The 1605(b) program, in its current form, does not provide specific guidance on how to account for the emission benefits of GHG emission reduction projects, such as geologic sequestration activities. However, in February of 2002, President Bush directed the Department of Energy, in consultation with the Department of Commerce, the Department of Agriculture and the Environmental Protection Agency (EPA), to enhance the measurement accuracy, reliability, and verifiability of the emission reductions reported to the program. Reforms to 1605(b) are to ensure that businesses and individuals registering reductions will not be penalized under a future climate change policy, and to give transferable credits to companies that can show real emission reductions. As part of this enhancement effort, the Department of Energy is also looking at methodologies for geologic sequestration. However, at this time it is uncertain whether specific guidance related to geologic sequestration will be developed.

3.2 Capture and Storage Activities Reported to Canadian GHG Programs

Several capture and storage activities have been reported to Canadian GHG programs, and one other program is developing accounting protocols for geologic sequestration activities. Among the project-based GHG programs in Canada, the Greenhouse Gas Emission Reduction Trading Pilot (GERT) program[16] has approved a project involving the capture and re-injection of CO_2 into a depleted gas reservoir, stating that the reduction is real, measurable, and verifiable.[17] As part of this project, all hydrogen sulphide (acid gas) and CO_2 are captured at the Jedney gas processing plant by Westcoast Gas Services and injected into a deep subsurface formation operated by Westcoast, instead of using conventional methods of sulfur recovery and CO_2 venting to the atmosphere.[18] GERT found the project to be additional or "surplus" to business-as-usual, as there are currently no restrictions on CO_2 emissions from gas processing, and acid gas re-injection is not required in British Columbia where the project is located.

CleanAir Canada, an Ontario-based non-profit, multi-stakeholder organization to promote emissions trading, reports that five percent of CleanAir Canada's approved emission reductions, or 2.24 million metric tonnes of CO_2 equivalent, are from geologic sequestration. Credits approved by CleanAir Canada undergo a rigorous review and reductions must be demonstrated as real, surplus, verifiable, quantifiable

[16] The GERT pilot trading program was a collaboration between the federal government, six Canadian provinces, industry associations and environmental groups. The pilot lasted for four years, from 1998 to 2002.
[17] GERT Quantification Guideline, Acid Gas Re-Injection, June 2002.
[18] "Westcoast Gas Services Jedney and Highway Gas Plants Operational" Westcoast Energy Press Release. July 24, 1997. web site: www.westcoastenergy.com/newsreleases/bak/1997jul24_0.html

and unique.[19] The registered capture and storage activities are reported by the GHG trading firm Blue Source LLC on behalf of Petro Source, a CO_2 pipeline operator who buys and aggregates waste CO_2 and methane (CH_4) captured from industrial processes in Texas.[20] Petro Source then transports and sells these gases to operators of EOR fields in Mississippi, Texas, and Wyoming. The CO_2 and CH_4 is gathered from vent stacks of natural gas treating plants that previously vented these gases to the atmosphere. A project "creation" report for this activity has been submitted to CleanAir Canada, covering accounting issues such as ownership, surplus, demonstration of "real" emission reductions, and emission baseline quantification and verification.

Protocols for project-based reporting of emission reductions from geologic storage activities are also being developed for Environment Canada's PERRL Initiative which announced its first tender for GHG emissions purchase agreements in the Fall of 2002. These protocols should be available in the late spring of 2003.[21]

In addition, capture and storage activities have been reported at the entity level in Canada. At least two companies have included capture and storage activities in their annual reports submitted to Canada's national GHG registry, also known as the Climate Change Voluntary Challenge and Registry (VCR).[22] The VCR requires validation of registered reductions; validation includes an evaluation of the company's emissions inventory and baseline procedures as well as individual project design and monitoring and verification protocols. Although the VCR provides some guidance for entity reporters in terms of required emissions, emission factors, boundaries, and emission baselines, the VCR does not provide specific guidance on how to account for individual GHG offset projects. In its 2002 submission, NOVA Chemicals reported emission reductions from the capture of CO_2 from the company's ethylene-polyethylene plant in Alberta to meet its company-wide emission reduction goal. The captured CO_2 is then used for EOR by an oil producer in the area. The report does not describe how much CO_2 is being sequestered or whether NOVA Chemicals and the oil company operating the EOR fields have established any formal ownership agreement regarding the claimed emission reductions.

The second capture and storage activity reported to the VCR is based on a somewhat different ownership arrangement because the reporting entity, EPCOR Utilities Inc., reports on a project-based emissions trade undertaken as a member of the Greenhouse Emissions Management Consortium (GEMCo). GEMCo is a consortium of Canadian energy companies focusing on market-based ways of reducing GHG emissions. In November 2000, CEMCo purchased an option for 600,000 metric tonnes of 2002 – 2012-vintage CO_2 equivalent emission reductions.[23] As part of this option agreement, captured waste CO_2 from industrial vent stacks in Texas is purchased, aggregated, transported, and sold for EOR in Texas and Wyoming by Petro Source, a CO_2 pipeline operator and the supplier of the emission reductions. EPCOR's individual share, as reported to the VCR, includes 180,000 metric tonnes of CO_2 equivalent, which will be delivered between 2008 and 2012 and will be used to meet EPCOR's emission reduction goal.[24]

3.3 Capture and Storage Reported Under the Activities Implemented Jointly (AIJ) Pilot Phase

Under the auspices of the U.N. Framework Convention of Climate Change (UNFCCC) the Activities Implemented Jointly (AIJ) Pilot Phase was introduced in 1995 to test the concept of implementing GHG

[19] CleanAir Canada, "CO_2 Project Activity (By Emissions)," web site: www.cleanaircanada.org/images/chart02.jpg For more information about the CleanAir Canada emission trading and project review process, visit: www.cleanaircanada.com

[20] URS Corporation. "Emission Reduction Credit (ERC) Creation Report for Petro Source's Capture of Vent-Stack CO_2 in Combination with Enhanced Oil Recovery Operations." March, 2001.

[21] The project areas being targeted under PERRL include: landfill gas capture and combustion, CO_2 capture and geological storage, renewable energy, and biological sinks. In the fall of 2002, PERRL announced the first auction round for emission reduction projects. Project proposals are currently being validated and results of the first auction round will be available in mid-2003 at www.ec.gc.ca/pdb/ghg/ghg_vc_e.cfm.

[22] For more information, visit CleanAir Canada's website: http://www.vcr-mvr.ca/reduction/index_e.cfm

[23] The Greenhouse Emissions Management Consortium, "Canadian Consortium of Energy Companies Agrees to Buy Emission Reduction Credits From CO_2 Pipeline Operator," Press Release, Den Hague, November 20, 2000. web site: www.gemco.org/petro_source_project.htm

[24] EPCOR Utilities Inc., "Voluntary Action Plan Progress Report 2001," Updated October 2002.

emission reduction projects jointly between two or more countries. The main criterion for project participation was that projects had to be additional to what would have occurred in the absence of the project activity. In 1998, the Belgian and Croatian governments reported on a CO_2 recovery project in a brewery in Zagreb, Croatia where fugitive CO_2 from the fermentation process in the Zagrebacka Pivovara brewery is captured and used for carbonation during beer production.[25] The project is financially viable without AIJ participation, but the project proponents argue that the project is additional as the technique used for CO_2 recuperation from beer fermentation is not yet wide spread in breweries in Eastern Europe and developing countries.

4.0 Inventory Guidance for Capture and Storage

Guidance for the reporting of GHG emissions have been developed for the purposes of preparing national and entity-level inventories of GHG emissions. The accounting methodologies developed within these systems may serve as an indicator of how geologic sequestration could be addressed and accounted for within various GHG reporting and offset programs. At this time, none of the different inventory systems provide direct guidance on the treatment of geological sequestration activities. However, several components of the capture and storage process are covered indirectly through analogous activities in the oil and gas sector and certain other industries. The following subsections summarize the relevant accounting methods for national- and entity-level inventory development.

4.1 National Inventory Reporting

On an international level, the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories and IPCC Good Practice Guidance and Uncertainty Management in National GHG Inventories Report state that GHG volumes vented to the atmosphere should be reported, while emissions that are injected (sequestered) should not be counted as emissions. Under this guidance any fugitive leaks that result from the handling of GHGs is required to be reported, and it is expected that CO_2 handled for capture and geologic storage would be accounted for using this existing methodology.[26] For operational gas injection and EOR, the IPCC Good Practice report provides default CO_2 emission factors for different stages of oil and gas production based on throughput and the number of wells.[27] However, no explicit reporting guidance is provided where waste CO_2 from natural gas production is injected for sequestration purposes and no guidance is provided for estimating CO_2 leakage during EOR. The capture of CO_2 from power generation is not addressed either. Under the IPCC guidelines it is uncertain how possible long-term leakage from the storage reservoir will be measured, whether through direct monitoring by the industry or estimated based on diffusion rates. The 1996 IPCC Guidelines are being revised and are expected to be completed by 2006.[28] These revisions will include detailed guidance on capture and storage.

A few countries indirectly address geologic sequestration through their national inventories. Currently both Australia and the U.S. require reporting of CO_2 emissions that are vented or flared from the upstream oil gas production/processing. Norway requires reporting of vented emissions only from the oil and gas sector, and consistent with the IPCC guidance, captured CO_2 from Statoil's Sleipner West field (and injected in a saline formation) are not reported.

Active geologic sequestration projects in the U.S. have to date been combined with EOR operations. Currently an estimation of the CO_2 emissions leaked from these EOR operations are not included in U.S.

[25] Report Submitted for Approval By the Belgian and Croatian National Authorities on Activities Implemented Jointly. July 1998. web site: unfccc.int/program/coop/aij/aijproj.html
[26] Treatment of Geological Sequestration within the National Greenhouse Gas Inventory, IPCC Workshop on Carbon Capture and Storage, Regina, Canada, November 18-21, 2002.
[27] Volumes injected into reservoirs need to be tracked, as data on throughput is needed to estimate fugitive emissions.
[28] IPCC. Draft Report of the Twentieth Session of the Intergovernmental Panel on Climate Change (IPCC)—Paris, 19-21 February 2003. Draft of March 28, 2003

inventories managed by the U.S. Energy Information Administration (EIA) and the EPA because most of the CO_2 recovered with the oil is recycled through re-injection. Moreover, EIA and EPA believe there is no current basis for estimating the quantity of vented CO_2 from EOR operations. The annual amount of CO_2 used for EOR is probably on the order of 8 million metric tons,[29] and fugitive emissions would be some fraction of that figure.

In some instances, waste CO_2 from natural gas processing and fertilizer plants has been used for EOR. The EIA inventory includes venting from natural gas processes as an emission source, but the EPA inventory excludes them to ensure that emissions are not double-counted or under-reported. With respect to fertilizer plants, CO_2 emissions are included in both the EIA and EPA inventories.[30]

4.2 Entity-Level Inventory Reporting

Public and private entities may also develop GHG emission inventories in order to determine their emission sources, prepare for any potential future regulation, report on their emissions to a GHG emissions registry, or take on a GHG emission reduction target. Guidance for entity level inventory reporting can be obtained from sources such as the WRI/WBCSD GHG Protocol, the American Petroleum Institute (API) Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry, and the Reporting Protocol of the California Climate Action Registry. In addition, The International Organization for Standardization (ISO) is currently developing guidance for entity-level GHG emissions reporting. The following two paragraphs summarize relevant emissions accounting and reporting boundary guidance.

The API addresses leaked, flared, and vented CO_2 emissions during upstream oil and gas processing, but does not address long-term leakage from sequestered CO_2. According to the API compendium, CO_2 emissions from vented and fugitive sources during EOR should be considered in a GHG inventory due to the potentially high CO_2 concentrations (from CO_2 flooding) associated with EOR operations. To assist entities in incorporating the additional CO_2 emissions from utilizing EOR with CO_2 flood or other CO_2 rich production streams, the API Compendium provides a sample inventory for a facility producing a CO_2 rich stream. The API is also in the process of developing a sample case study to illustrate accounting procedures for capture and storage activities involving oil and gas processing.

The WRI/WBCSD GHG Protocol acknowledges CO_2 capture and geologic storage in its definition of sequestration: "the uptake and storage of CO_2. CO_2 can be sequestered by plants and in underground/deep sea reservoirs."[31] However, the WRI/WBCSD GHG Protocol does not provide inventory guidance that specifically addresses CO_2 capture and storage. The California Climate Action Registry does not address any CO_2 sequestration activities.[32] ISO has established a technical committee that has begun development of ISO 14064: Guidelines for measuring, reporting and verifying entity and project-level greenhouse gas emissions.[33]

There are many instances where the ownership and operation of capture and storage activities are shared between multiple entities. To account for multiple ownership operations, the API compendium recommends that two parallel inventories could be developed for each entity, one based on a "100% as operated" approach, while the second tracks facilities and operations in which the entity holds a majority "equity share." The WRI/WBCSD GHG Protocol instructs entities to define their organizational

[29] The U.S. Department of Commerce reports total sales of industrial carbon dioxide in 2000 were approximately 13 million metric tons annually, while past Freedonia Group, Inc. reports have reported that approximately 5 million metric tons are used for purposes other than enhanced oil recovery.

[30] Both assume that feedstock use of natural gas to make nitrogenous fertilizers is a non-sequestering use and 100 percent of CO_2 is emitted.

[31] WRI/WBCSD. *The Greenhouse Gas Protocol. A Corporate Accounting and Reporting Protocol.* October 2001. http://www.ghgprotocol.org/standard/ghg.pdf

[32] The California Climate Action Registry. General Reporting Protocol. October 2002. http://www.climateregistry.org/files/general_reporting_protocol_102102.pdf

[33] ISO. Environmental Management. The ISO 14000 Family of International Standards. Web site: www.iso.ch/iso/en/prods-services/otherpubs/iso14000/index.html

boundary in a manner that is consistent with that which is established for financial reporting purposes. In general, the GHG Protocol specifies that an entity should report 100 percent of the GHG emissions from an entity or facility that is wholly owned or controlled. For a facility or entity that is jointly controlled or under significant influence (e.g., voting interest), the equity share of GHG emissions should be reported. Regarding operational boundaries, the GHG Protocol directs entities to report both direct and indirect emissions.

The California Registry only allows entity-wide emissions reporting. When defining organizational boundaries, the California Registry requires entities to inventory those facilities and operations that fall within the chosen geographic boundaries. For facilities that are wholly owned, the California Registry requires that all of the associated emissions be reported. For facilities that are partially-owned, leased, or held by operating license, entities must report based on contractual arrangements that define ownership and/or emissions responsibility, if they exist, or report based on either their management or equity share.[34]

5.0 Accounting Issues for CO_2 Capture and Storage Activities

As the emission accounting methodologies for geologic sequestration continue to be developed and refined, and this type of project is incorporated into the emerging GHG reporting and trading programs, there are a number of specific issues related to capture and storage that should be considered. The following paragraphs summarize some of the major accounting issues relevant to project-based and entity-level reporting of CO_2 capture and storage activities.

5.1 Project Reporting

Project-level reporting focuses on individual project-based GHG reduction activities that provide a snapshot of emissions and emission reductions related to one particular project activity without considering other emissions of the entities involved. In the following we summarize accounting issues that may be relevant to the reporting of CO_2 capture and storage projects.

5.1.2 Emissions Sources and Emissions Quantification. A number of different sources contribute to GHG emissions during the life of a capture and storage project. These include the physical leakage of CO_2 during the capture, transportation (e.g., through pipeline losses), and injection processes, as well as emissions generated from the extra energy that will be consumed to power these processes. Hence, the net emission reductions from the storage project are less than the amount captured at the power plant facility and less than the amount actually injected into the ground for storage. For example, if a capture and storage project stores a total of one hundred metric tons of CO_2 in a saline reservoir, while 10 tons of CO_2 is emitted while powering the equipment to capture, transport and store the CO_2, the net emission benefits of the project would equal 90 tons of CO_2. In general, the following issues are relevant to estimating the emission baseline and project emissions scenarios:

1. Emission baseline or reference case scenario

The emission baseline – or the projected emissions without the project – of a CO_2 capture and storage project will depend on whether the project involves a retrofit of an existing facility or a new facility. In some cases the CO_2 capture technology will be installed in conjunction with the construction of a new power generation or industrial facility, but it is also possible that the CO_2 capture technology will be added as part of a retrofit project. The baseline scenario will differ for each case.

The emission baseline of a CO_2 capture project involving the installation of *a new power generation or industrial facility* would be based on the emissions (direct and indirect[35]) associated with the type of

[34] The California Climate Action Registry.

[35] Inclusion of both direct and indirect emissions is typically required in project-level reporting, whereas the extent to which indirect emissions are included in entity-level reporting depends on the specific requirements for indirect reporting. For example, some entity-level programs may not require facilities to include emissions generated during transportation of materials or employees in the estimate of corporate emissions.

facility that would have been installed in the business-as-usual scenario. For example, when considering a new baseload facility in the U.S., the most likely alternative for an integrated gasification combined cycle (IGCC) plant with CO_2 capture technology would be a natural gas combined cycle (NGCC) plant or conventional pulverized coal (PC) plant, depending on resource availability, because these are often the most economic of the alternatives. In this case, the projected emissions of a NGCC or PC plant would represent the reference case scenario.

In a capture project based on a *retrofit of an existing unit*, the emission baseline would consist of projected CO_2 emissions (direct and indirect[36]) associated with the specific facility where the CO_2 is to be captured. This estimate could either be based on a historic analysis of emissions at the site (i.e. a 3-year average) or a projection of expected emissions over the life of the project.

In projects where the captured waste CO_2 will *replace the use of CO_2 extracted from naturally occurring reservoirs*, the emission baseline would also account for emissions associated with the natural CO_2 extraction process, including the emissions that would be generated to produce power for the CO_2 drilling, compression, and transportation as well as the physical leakage of natural CO_2 during transportation.

2. Project Emissions

The estimation of CO_2 emissions of the project itself would include an analysis of all emissions sources from the unit where the CO_2 is captured, the capture and storage process, and any potential CO_2 losses. The amount of sequestered CO_2 would then be subtracted from these emission sources to derive total project emissions, as shown in the following equation:

$$CO_2E \text{ Emissions of Project} = (E_{Base} - E_{sto}) + E_{cap} + E_{com} + E_{tran} + E_{see} + E_{inj} + E_{leak}$$

Where:

CO_2E	= CO_2 Equivalent
E_{base}	= Emissions at unit, from which CO_2 will be captured (baseline)
E_{sto}	= CO_2 physically deposited for storage in the geologic formation
E_{cap}	= CO_2E emitted from energy used for capture or separation
E_{com}	= CO_2E emitted from energy use during compression of CO_2
E_{tran}	= CO_2E emitted from energy used to transport CO_2
E_{see}	= CO_2 leaked during transportation
E_{inj}	= CO_2E emitted from powering CO_2 injection equipment
E_{leak}	= CO_2 released due to potential leakage from storage site

The difference between the baseline emissions and the project emissions would represent the net CO_2 reductions of the capture and storage project.

5.1.2 Indirect Leakage. Some carbon capture and storage projects may have indirect effects on GHG emissions outside the project boundary; that is, the project may lead to an increase in emissions somewhere else that would not have occurred in the absence of the project. These indirect effects can be referred to as *indirect leakage*. Potential indirect leakage from geologic carbon storage projects include increased fossil fuel use resulting from enhanced resource recovery or decreased demand for electricity due to higher production costs. For example, if EOR increases oil production and reduces associated costs, consumers may chose to use oil rather than another fuel type, or consume more of it. Likewise, it is possible that the installation of CO_2 capture and storage technology at a coal-fired power plant may increase the price of the electricity from a particular generating facility, causing consumers to purchase their electricity from other power producers. None of the capture and storage projects reported to existing GHG programs have addressed any potential indirect leakage effects.

[36] Ibid.

Determining whether and to what degree indirect leakage from CO_2 capture and storage projects should be accounted for involves a tradeoff between completeness and complexity. Accounting for indirect leakage requires additional data collection, analysis, and assumptions of what may happen in the future and may thus increase the transaction costs of project reporting. However, the consideration of indirect leakage may also lead to a more accurate estimate of emissions.

5.1.3 Physical Leakage/Fugitive Emissions. Physical leakage refers to the amount of CO_2 leaked to the atmosphere during the process of capturing, transporting and injecting waste CO_2 into the ground, and any potential CO_2 that may be leaked from the geologic repository after the time of injection. Methods and emission factors for estimating physical leakage during the capture, transport, and handling of CO_2 can be found in the IPCC inventory guidance and the API Greenhouse Gas Compendium. There are no standard emission factors for estimating leakage from EOR operations based on CO_2 injection rates. However, the API GHG Compendium does provide guidance for estimating CO_2 leakage at the individual facility level. None of the existing inventory methodologies address methods for estimating physical leakage from a permanent storage site and none of the capture and storage projects reported to existing GHG reporting and offsets programs have addressed the issue of long-term leakage.

Quantifying leakage from geologic repositories could be accomplished by using monitoring and detection technologies, many of which are currently in use today. Technologies used to monitor CO_2 include infrared analyzers and continuous monitoring sensors, remote sensing by satellites, gas chromatographs, and flowmeters.[37] To monitor CO_2 movement and physical leakage, geophysical techniques, such as seismic and electromagnetic methods, are being researched and evaluated. Many carbon capture and storage studies are also underway to further develop and apply methods for monitoring diffuse or low-level surface leaks at geologic storage sites.[38]

To ensure standardization of the monitoring process, protocols could be established that outline generally accepted technologies and procedures for monitoring stored CO_2.

5.1.4 Permanence. Permanence refers to the length of time that CO_2 emissions are removed via storage projects before being re-released to the atmosphere, and is an important issue in the consideration of all types of sequestration activities. Compared with terrestrial sequestration, geologic storage projects are generally considered to be permanent, although research is still being undertaken to track migration and develop tools to detect physical leakage of CO_2 from storage sites over time. Preliminary results from actual geologic carbon capture and storage projects, including the Sleipner project, in which CO_2 is injected into saline aquifers below the North Sea, have shown no evidence of physical leakage to date. However, monitoring equipment is still being refined and may thus in the future detect leakages that have currently been left unidentified.

It is believed that each type of storage site will demonstrate different geological qualities affecting the ability to permanently store injected CO_2. Current research, further development of CO_2 monitoring tools, and appropriate site-selection (e.g., evaluation of well and seismic data and determination of structural confinement) will help ensure that carbon storage projects are conducted at permanent and environmentally sound sites. If it is found that some geologic reservoirs eventually re-release some or all of the sequestered CO_2 to the atmosphere, site-specific discount rates could be established to account for potential physical leakage in areas where the permanence cannot be confirmed by using available tools and methods. In the example of the Rangely Weber Sand Unit CO_2 Injection Project reported to the 1605b program, the reporter claims permanence based on the following three reasons: any CO_2 that is produced with the extracted oil is separated and reinjected back into the reservoir, the reservoir's depth

[37] Sally Benson. Monitoring to Ensure Safe and Effective Geologic Sequestration of Carbon Dioxide. IPCC Workshop on Carbon Capture and Storage, Regina, Canada, November 18-21, 2002; and Sally Benson (2002). Lessons Learned from Natural and Industrial Analogues for Storage of Carbon Dioxide in Deep Geologic Formations. LBNL #51170, technical report for BP-DOE CRADA under contract DE-AC03-76F00098.

[38] Sally Benson (2002). Lessons Learned from Natural and Industrial Analogues for Storage of Carbon Dioxide in Deep Geologic Formations. LBNL #51170, technical report for BP-DOE CRADA under contract DE-AC03-76F00098.

and geologic characteristics are suited for permanent storage, and the wells are plugged in accordance with State regulations to prevent leakage to the surface or other geologic formations.[39]

5.1.5 Measurement, Monitoring and Verification Requirements. The degree of measurement, monitoring and verification (MM&V) required could vary from estimations based on fuel source to direct measurement of the CO_2. Existing projects that have been registered and/or generated trades in the nascent GHG market have represented this spectrum. In many ways what MM&V requirements will be appropriate is contingent on the length of the project. For example, for the GERT project cited earlier the evaluation team found that because only one year of reductions were being registered, reductions reported based solely on estimation were appropriate.[40] The committee noted that for a large project over several years, a direct measurement approach would be needed.

A different set of factors become important when considering storage of CO_2 over decades or centuries. Reliable, affordable and practical methods are needed. The technologies for below-ground (in reservoir) MM&V draw upon a significant capability developed for fossil resource exploration and production. Work in below-ground MM&V options include surface to borehole seismic, micro-seismic, and cross well electromagnetic imaging devices to characterize reservoir properties and changes post CO_2 injection. The area of above-ground MM&V technology is less mature and is focused on detecting leaks or deterioration in the reservoir, and assessing ecological impacts of geologic carbon storage. In addition to technologies for measurement, standard protocols for MM&V are needed.

5.1.6 Additionality. Additionality is the requirement that the emission reductions in question would *not* have occurred in a business-as-usual scenario. There are several approaches to evaluating additionality—each having different degrees of stringency and providing different levels of environmental integrity. Those projects that would be uneconomic without carbon financing are considered to meet "investment" additionality criteria; those that are not required by existing laws and regulations are "surplus" additional; and those with significant barriers to implementation are "barrier" additional. In a more general sense, those that can be shown to result in real emission reductions that would not have otherwise taken place are "environmentally" additional.

Whether or not a CO_2 capture and storage project is considered an additional GHG reduction measure depends on the type of storage method used and the degree of stringency used in evaluating additionality. For those geologic storage projects that have the sole purpose of avoiding the release of CO_2 into the atmosphere—such as the Sleipner CO_2 injection project in the North Sea—it is much easier to make the case for additionality, as it is hard to argue that the project would have been implemented otherwise. On the other hand, those projects with value-added benefits such as enhanced resource recovery or re-use (e.g., the Weyburn EOR project in Saskatchewan—a project that captures CO_2 from an industrial processing plant in North Dakota and delivers it via pipeline to the Weyburn Oil Field for use in EOR) may have taken place anyway and may not in some instances be considered additional. In the example of the Petro Source/Blue Source LLC project submitted to the Clean Air Canada program, which involves captured waste CO_2 for EOR projects in West Texas, the reporter demonstrates additionality using the test of "surplus" to applicable state and federal regulations and voluntary commitments.[41]

Because CO_2 is an economic resource that can be used to improve oil recovery, a common practice in EOR projects has been to extract CO_2 from naturally occurring geologic reservoirs, transport it through pipelines to oil fields and recycle it at multiple oil wells leaving only a small fraction of CO_2 permanently stored in the depleted oil well.[42] Some additionality tests would not grant credits for the fraction of CO_2

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[39] Energy Information Administration. Voluntary Reporting of Greenhouse Gases, web site: http://www.eia.doe.gov/oiaf/1605/current.html

[40] The CO_2 content of the inlet gas is compared to the CO_2 content of the sales gas, along with appropriate calculations that account for leakage. *Jedney Acid Gas Reinjection Project, Offer to Sell, Technical committee Review Report*. June 10, 2002.

[41] URS Corporation. "Emission Reduction Credit (ERC) Creation Report for Petro Source's Capture of Vent-Stack CO_2 in Combination with Enhanced Oil Recovery Operations." March, 2001.

[42] The typical storage rate is 2,000 standard cubic feet (scf) of CO_2 per barrel oil recovered. NETL. "The New Carbon Sequestration Roadmap" January 2003.

that is permanently stored, arguing that only the CO_2, which is intentionally left in the ground (when it could have been reused for EOR in another well) should be considered additional.

5.1.7 Ownership. Because CO_2 capture and storage projects are likely to involve several parties, each bearing a different degree of participation and risk in the implementation of the project, multiple entities could potentially seek full or partial ownership of CO_2 capture and storage credits. Of the capture and storage activities listed in Tables 1 and 3, only two involved one project participant; the TXU Ranger Exhaust Gas Project and the West Coast Gas Services Acid Gas Re-injection Project. The remaining projects and trades involved more than one participant, and in these cases only one of the participants reported or claimed the emission reductions. For example, the RWSU CO_2 Injection Project involves a joint venture between companies that hold oil and gas leases covering an oil reservoir. Chevron USA operates the RWSU, which purchases CO_2 from a gas plant owned by Exxon-Mobil.[43] Although Exxon-Mobil captures the CO_2, RSWU is the reporting entity that lays claim to the sequestered emissions.

There are several different ways that an entity can lay claim to the emission reductions resulting from a capture and storage activity. Project participants may include the industrial entity or power plant that captures the CO_2, the owner of a CO_2 transport pipeline, an oil company that injects the CO_2 to displace oil from a well, and the owner of the leased land on which the oil company is drilling and where the CO_2 will remain sequestered indefinitely. The separation and capture phase may require the largest investment, but the owner of the land may have the greatest risk in the project if he/she is responsible for ensuring permanence of the credits.

Typically, project participants will document the credit title agreement in a contract, based on perceived risks and financial involvement. The important issue in terms of developing GHG accounting rules is identifying and avoiding double-counting of CO_2 reductions in the case that more than one party reports on the emission reductions. This is particularly important in cases where the entities that capture the CO_2 are already reporting on such emission reductions as part of their corporate GHG inventories. Standards for ownership could be defined by the specific GHG reporting program, for example, through a requirement that capture and storage activities involving more than one owner must submit a statement confirming legal title to the claimed emission reductions. Alternatively, GHG programs and project developers could refer to available guidance on establishing GHG contracts, such as the draft standards for carbon contracts developed by the International Emissions Trading Association (IETA).[44]

5.1.8 Uncertainty. There are many factors of uncertainty inherent to emission reduction projects and sometimes it is not feasible to estimate future emissions based on direct measurements alone. In such cases, when emissions reduction estimates are prepared, they rely on engineering design studies, mass balance estimates or modeling instead of direct measurement of CO_2 emissions. EOR projects are a good example of a reduction project that lends itself to direct measurement (volume of CO_2 transmitted is metered for sales purposes). However, even when direct measurement is possible for one aspect of the project, estimation will be needed to account for leakage. It is impossible to eliminate uncertainty, but use of accepted estimation protocols such as the American Petroleum Institute's Compendium of Greenhouse Gas Emissions Estimation Methodologies and the WRI/WBCSD Greenhouse Gas Protocol can reduce this uncertainty.[45]

As with any new area of technology development, there is a great deal of uncertainty as to the timing and implementation of geologic sequestration technologies. Enhanced resource recovery with CO_2 is the only active geologic sequestration practice in the U.S. at this time. The future of enhanced coal bed methane

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[43] Energy Information Administration. Voluntary Reporting of Greenhouse Gases, web site: http://www.eia.doe.gov/oiaf/1605/current.html

[44] International Emissions Trading Association (IETA). "Carbon Contracts Cornerstones: Drafting Contracts for the Sale of Project Based Emission Reductions." Discussion Paper No. 02-01, Version 1.2. 2002.

[45] Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry, Pilot Test Version, April 2002 is available for purchase through the American Petroleum Institute. WRI GHG protocol is available at www.ghgprotocol.org.

(ECBM) or storage in saline aquifers is uncertain, but it is likely that a GHG reporting framework that accommodates sequestration via EOR can be robust enough to include other types of geologic storage.

5.2 Entity-Level Reporting

Entity-level GHG reporting refers to the accounting of all GHG emissions from inside the boundaries of a given entity, such as a private company, educational institution, or public organization. Entity-level reporting encourages organizations to consider all of the GHG emissions for which they are accountable. When GHG emissions and emission reductions are reported at the entity level, project-level activities are not recognized separately but are included in the overall inventory of entity emissions. Under entity reporting, some of the more complicated project-specific accounting issues, such as additionality evaluation and indirect leakage, are not addressed. Rather guidance for entity reporting focuses on entity boundaries and ownership; treatment of direct and indirect GHG emissions; emission sources, quantification methods and emission factors; uncertainty; and, in some cases, emission baseline development.

The major issues related to the treatment of capture and storage activities in entity-level reporting relates to quantification of emission sources and the definition of organizational boundaries. With respect to emissions quantification, some inventory guidance is available from existing inventory protocols. This guidance covers emissions from the capture of waste CO_2 from industrial and power generation processes and the transport and use of the CO_2 for EOR. This includes guidance to estimate CO_2 emissions leaked from the EOR process at the facility level. However, issues that have not been addressed are methodologies for estimating CO_2 emissions leaked during enhanced gas recovery and ECBM. Methods for estimating potential CO_2 leakage from geologic repositories after the point of storage, and standards for monitoring this potential leakage, will also need to be addressed.

A second issue significant to entity reporting of capture and storage activities is the treatment of ownership, or the boundary for what GHG emissions to include in the entity report. As mentioned in the section on entity-level inventories, the inventory boundary of an entity is typically determined according to management (wholly-owned or controlled) or equity control (voting interest). Following this guidance entities can only report on emissions and emission reductions from operations where it has a major ownership or equity share. However, many capture and storage activities involve more than one project participant as the parties that capture, transport, and inject the CO_2 may not all belong to the same company. As a result, it is likely that more than one entity could report on the same capture and storage activities and appropriate tracking systems will therefore be necessary to avoid double-counting.

In the case where a GHG registry only allows entity reporting and excludes GHG offsets, entities may not be able to report on their participation in a capture and storage activity because their role takes place after the point of CO_2 capture. According to existing inventory guidance, waste CO_2 that is captured instead of vented to the atmosphere does not count as an emission. This means that unless some other contractual agreement is negotiated between the participants, the emission reductions of the geologic sequestration activity would be counted at the point of capture. Thus, by default, the entity that captures the CO_2 would benefit from the capture and storage activity in terms of reduced overall emissions instead of the entity, which injects the CO_2 into the ground.

6.0 Conclusion

CO_2 capture and geologic sequestration is already an option for GHG markets and voluntary reporting programs, demonstrated by the activities that have been funded, traded, and reported, as described in Sections 2 and 3 above. Transaction values vary by trading program and type of GHG reduction activity. As the number of CO_2 capture and storage activities grows, there is a growing need for reliable and common accounting practices. Some guidance can be obtained from existing inventory guidance for developing national and entity-level inventories. However, a number of issues will still need to be addressed. Project-based reporting issues include clarification of additionality, leakage, permanence, ownership and monitoring and verification. For entity-level reporting, there will be a growing need for additional guidance on documenting the use of CO_2 in EOR activities, especially for projects that involve permanent CO_2 storage rather than CO_2 recycling in oil wells.