CONFERENCE PROCEEDINGS

Sequestration and Success: The Cost Impact of Reporting Protocols and Other Requirements

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1. Background

Given the broad range of responses to global climate change by multiple governmental organizations at the state and federal levels, significant variation currently exists within the United States (U.S.) with regard to regulatory requirements for carbon capture and sequestration projects. The Augusta Systems (Augusta) research team under multiple research opportunities has reviewed these requirements for both terrestrial and geologic carbon sequestration projects. More specifically, in 2005 under a U.S. Department of Agriculture (USDA) Small Business Innovation Research (SBIR) grant entitled, "Economic Feasibility Study of Agricultural Coops as Catalyst in GHG Markets", the Augusta research team assessed the feasibility of agriculture-based cooperatives (coop)s to market greenhouse gas (GHG) emissions reduction tradable units (ERTU)s (Gandee, 2006). Further, in 2006 as a continuation of the efforts the Augusta research team conducted under Phase I of the Southeast Regional Carbon Sequestration Partnership (SECARB), the team began regulatory research efforts under Phase II. The Augusta Phase II research task focuses on the current national and international monitoring and accounting protocols. The information generated from these projects will be used to provide basic information on the current regulatory environments surrounding carbon sequestration, as well as the potential future requirements that may develop for voluntary and mandatory GHG protocols.

These research projects have enabled the Augusta team to accumulate a knowledge base about the current and expected regulatory environment surrounding carbon sequestration. Regulatory requirements can either deter the development of carbon sequestration projects or provide for the efficient implementation of the projects. This document presents the basic current and expected regulatory concerns associated with terrestrial and geologic carbon sequestration projects. More specifically, the underlining objective is to present the regulatory issues associated with these types of projects, so that in future public policy, regulations, and permitting requirements will be implemented in the most effective manner.

The regulatory issues that will be presented in this paper are as follows:

- Provide background research information on the transactions costs associated with terrestrial carbon sequestration projects;
- Present basic regulatory concerns associated with the current geologic carbon sequestration projects; and,
- Present basic information regarding monitoring and verification protocols on geologic carbon sequestration projects.

This paper therefore, presents detailed information on terrestrial sequestration regulatory requirements as well as summarizes the major regulatory concerns for geologic sequestration projects.

2. The Role of Transaction Costs in Establishing Markets and Novel Commodities

Previous economic research reveals that a significant obstacle to initiating novel markets are the transaction costs related to the production of a commodity (Davidson and Weernsick, 1998; Coase, 1992). For example, typical transaction costs associated with GHG ERTUs are monitoring and verification of GHG emissions reductions, which entail quantifying the amount of GHG emissions that have been reduced through carbon sequestration or GHG emissions reduction projects (CCX, 2003). Transaction costs are defined as the expenditures spent to derive a successful exchange of goods and services. In environmental-based trading markets, such as emissions trading markets, emissions contracts are used to meet regulatory and emissions requirements. Private firms that invest in GHG emissions reduction assets, such as carbon sequestration projects, can observe the following transaction costs (Deepananda P.B. Herath and Weernsink, 1999):

- **Program and project development information cost**: These activities can entail outreach and educational efforts prior to the development of a project**.**

- **Partner and/or contract negotiation costs:** The costs are usually fees for legal services (Wilder, 2005).

- **Contract enforcement costs:** The costs are usually fees for legal services (Wilder, 2005).

- **Monitoring environmental assets:** This activity includes the quantification of emissions and emissions inventory, which includes various engineering activities (this process is further described in the following sections).

When initiating novel markets, regulatory organizations also experience transaction costs, which can include (Deepananda P.B. Herath and Weernsink, 1999):

- **Program enactment costs of a policy**

- **Program implementation costs**

- **Monitoring costs incurred by the governmental entity**

- **Prosecution cost of non-compliant firms**

Specific GHG emissions programs, voluntary or mandatory, governmental-based or non-profit, may also generate additional transaction costs for participating organizations through program requirements, such as: GHG emissions reduction baseline determination as well as GHG emissions reduction registration, verification, and possibly certification (CCX, 2003; Michaelowa, 2003; Wilder, 2005). The transaction costs associated with specific GHG program requirements will be described further in the following sections. Many GHG programs in the U.S. and internationally have a variety of requirements for carbon capture and sequestration projects. For example, all of the requirements presented would be observed under GHG emissions reduction projects developed to meet Kyoto Protocol emissions standards; however, only some of these requirements are observed by U.S. GHG programs. The California Climate Action Registry (CCAR) requires registration of carbon storage, monitoring of forestation projects, and certification by a third party for forestation projects. On the other hand, the Chicago Climate Exchange (CCX) requires a registration of expected GHG emissions storage, implementation of a monitoring plan, and verification of sequestered carbon. In addition, CCX observes on-farm conservation tillage projects and forestation based projects, two projects that are not recognized by the CCAR.

The numerous differences between GHG programs have resulted in the establishment of a variety of regulatory requirements for program participants. As noted previously, the regulatory requirements are transaction costs for the program participants in emissions trading programs. For example, under GHG programs suppliers are required through the development and submission of monitoring and verification research documentation to determine that the commodities have been generated. These program transaction costs are basic program requirements under the established GHG regimes. Therefore, in this research article, transaction costs will be referred to as the regulatory requirements or costs in the following sub-sections.

3. Transaction and Regulatory Requirements Associated with Terrestrial Sequestration

During the USDA SBIR research project, the current GHG emissions trading programs and the associated requirements were extensively reviewed. The GHG emissions trading markets are in the early phases of development in the U.S. and internationally. Governmental and private exchange programs have provided the mechanisms to maintain and operate the emissions markets. Such

programs are currently operating in Europe under the European Emissions Trading System (ETS). In the U.S. the most notable trading program is the CCX, a private voluntary GHG program. Additionally in the U.S., state and regional GHG programs have been created that would support future GHG emissions trading activities, for example the CCAR.

Multiple GHG programs allow for the development of GHG ERTUs through the utilization of farm lands and farm-business operations. These projects include on-farm forestation, conservation tillage, and methane reduction projects. The Augusta research team assessed the financial viability of two scenarios that would entail the marketing of GHG ERTUs by agriculture-based cooperatives:

- **Concept A:** An established farm cooperative that markets GHG ERTUs.

- **Concept B:** The development of a new private entity that organizes multiple cooperatives to market GHG ERTUs.

These concepts would require farm owners to generate terrestrial carbon sequestration projects (i.e., forestation or conservation tillage projects) or GHG emissions reduction projects (i.e., on-farm biogas recovery projects). A centralized organization such as a farm coop on the other hand, would bundle, register, monitor, and verify the on-farm GHG emissions reductions. This hypothetical organization would specialize in these services which could ultimately minimize the project costs. There are costs in addition to those associated with regulatory requirements that are observed in our proposed concepts, such as operating cost. For this research project the regulatory costs reviewed were those associated with terrestrial carbon sequestration projects and included the following GHG program requirements:

- **Monitoring:** Monitoring entails activities by the proponent to measure the GHG reductions/removals and to quantify the resulting credits using the approach specified in the validated project proposal in the present (USDOE, 1999).

- **Verification:** Verification entails a third party review of quantification reports to confirm the materiality accuracy and quality of the evidence supporting the emissions reductions being claimed and the appropriateness of the monitoring and risk management activities (USDOE, 1999).

- **Certification:** Certification refers to the outcome of the verification process and entails accrediting emissions reductions following verification (USDOE, 1999).

- **Emissions Reduction Participating Agreement (ERPA) negotiation cost:** ERPA negotiation costs are observed typically in GHG emissions trading programs but are considered costs for legal services required to settle an ERPA contract between a project developer and an entity desiring emissions reductions.

- **Validation or measurement:** Validation or measurement of GHG emissions reductions entails estimating the carbon sequestered due to land and farm operation changes prior to the implementation of project activities (PCF, 2003).

For this project, a business survey plan was developed to extract the costs of these project requirements listed above from private, academic, and government professionals. A telephone questionnaire survey was used by the research team to obtain the necessary cost information. There were numerous financial assumptions supporting the feasibility analysis. The basic data regarding the program requirements listed above are dependent on external data resources. For example data from the USDA National Agriculture Statistics Service (NASS) on the average farm size was utilized. Additionally, some of the data resources were supplemented using data from various governmental organizations. Nevertheless, the basic cost estimates used for this analysis are presented in following table.

Table 1. Regulatory Costs for Terrestrial Sequestration Projects

Cost Type	Specific Assumption Revealed By Sample	Cost Estimates
Validation	"Not greater than $50,000.00" in year one	Between $0.00 and $50,000 based on the assumed GHG program GHG ERTUs have been registered
Monitoring	Bio-gas Recovery Systems	$3000 in the initial year and $1,000 in the following years
Monitoring	Soil Sampling Measurement Technologies	$.10 to $13.00 per ton of carbon
Monitoring	Soil Sampling Measurement Technologies	$.50 to $3.00 per acre
Verification	Afforestation	$12,000 to $28,000 per year
Verification	Soil Sampling Measurement Technologies	$12,000 to $28,000 per year
Verification	Afforestation	$3,000 to $5,000 per year
Verification	Bio-gas Recovery Systems	$5,000 per year
Certification	Variation in Costs Through Time	$10, to $25,000 for first year and $5,000 to $12,000 for following years

The cost information presented above was used to estimate the present value of an investment of GHG ERTUs. The costs were appropriately discounted and expected revenues estimated to create Net Present Value (NPV) estimates for numerous business scenarios of farm coops that market GHG ERTUs. The revenues were developed from an assumed transaction in GHG ERTU markets, including the CCX. Nevertheless, given the scenarios assumed in the analysis, an extensive level of soil carbon can be sequestered and numerous farm acres are required for these scenarios. Thus, the monitoring costs for soil carbon sequestration activities were assumed to be roughly $63,000 annually which is the most extensive regulatory cost. On the other hand, for bio-gas recovery projects it was assumed that the first year costs could be $3,000 and $1,000 in the following years. The monitoring costs between the GHG emissions reduction technologies are a dramatic difference for project developers. These costs can directly affect the ability of project developers to plan as well as ultimately impact the implementation of carbon sequestration projects. For example, in the USDA SBIR project conservation tillage projects typically did not provide a return on the investment, as a result of insufficient levels of sequestered carbon and the extensive monitoring costs.

The above costs were utilized to estimate the likely financial returns from a farm coop that would sell GHG ERTUs. Additionally, a basic financial scenario analysis was developed to observe the likely variation in financial returns given a change in the regulatory costs, specifically validation and certification costs. These forms of costs are not consistently observed by GHG programs and in turn,

could be volatile. There are additional regulatory costs that could be incurred by carbon sequestration project developers, including registry costs.

4. Overview of Potential Monitoring and GHG Accounting Issues

The development of geologic sequestration projects currently must adhere to a number of permitting and regulatory requirements. The regulatory requirements are likely to increase with the creation of future public-policies associated with carbon sequestration. In this section of the document the current regulations surrounding geologic sequestration projects are presented, in addition to the expected monitoring requirements that could result in the future.

4.1 Current Geologic Carbon Sequestration Regulations

The Augusta research team under the SECARB program has been actively researching the regulatory environment surrounding the SECARB field test sites. In the Southeastern States there are also numerous permitting requirements with which carbon sequestration project developers must contend. The current regulations and permitting requirements in the southeast affecting the SECARB field teams include the following:

- **National Environmental Policy Act (NEPA), Environmental Impact Statements (EIS)**
- **Safe Drinking Water Act (SDWA), Underground Injection Control requirements**
- **Carbon liability concerns**
- **State-level drilling permits**
- **U.S. Department of Transportation carbon dioxide transport permits**
- **Geologic sequestration project close-out requirements**

The costs associated with these regulatory and permitting requirements will not be examined quantitatively but are currently being contemplated by the SECARB field teams. As part of the regulatory activities under SECARB, the team is forming a SECARB Regulatory Working Group (RWG) to examine the major regulatory concerns with carbon capture and sequestration projects. The SECARB field team will probably not be required to implement all of the regulatory requirements listed above. Nevertheless, the governmental programs presented previously could be extensive in the initial years of project development in terms of permitting costs and administrative labor hours. These costs however are not as extensive as the monitoring and verification process presented in the following sections.

4.2 Monitoring Geologic Sequestration Requirements

Additionally, under the SECARB program the Augusta research team has been tasked with reviewing the current GHG accounting and monitoring protocols on a state, national, and international level. To date, the research team has reviewed the existing terrestrial sequestration protocols from the Canadian GHG Off-set System, the future Regional Greenhouse Gas Initiative (RGGI), and the CCAR. In the near future, this research will also include a review of International Standardization Organization GHG Protocol – 14064.

In the event that more restrictive GHG programs are initiated at the federal or state levels in the U.S. that recognize geologic sequestration projects as a viable GHG emissions offset option, there could be extensive regulatory requirements surrounding these types of projects. The regulatory requirements in the future could be equivalent to the permitting concerns presented above, in addition to the future

GHG program requirements observed in the typical GHG programs and examined in the Augusta USDA SBIR research project.

The GHG program costs that could potentially affect carbon capture and sequestration projects in the Southeast and on a national level have not been examined by the SECARB effort. These costs include ERPA negotiation costs, validation, and certification. Once again, these costs were estimated during the Augusta USDA SBIR research project and were presented in the previous section. On the other hand, the monitoring and verification services will vary by specific project. The monitoring and verification process, which has been reviewed extensively during the SECARB effort consists of continually developing observations of the geologic sequestration sites using the best available monitoring and verification technology options for the project sites. The monitoring and verification cycle is dynamic and includes an intensive process of measurement, modeling, verification, and risk analysis that is defined as follows:

- **Pre-project measurements:** Uses technology such as, seismic observations, to determine well characterization.

- **Modeling:** Determines the well structure, properties, and future sensor technologies.

- **Monitoring:** The initial monitoring during the injection phase of a geologic sequestration project entails measuring the levels of carbon dioxide injecting, carbon dioxide location and displacement, and storage integrity. The two major monitoring activities include techniques for tracking lateral migration of carbon dioxide and tracking carbon dioxide leakage outside the reservoir. The technology options for this phase of the geologic sequestration projects will be presented in the following paragraphs.

- **Performance and risk analysis:** Implementation of various probability analyses for leakages, injection efficiency, and carbon dioxide in place.

Following the injections of the carbon into geologic formations the modeling, monitoring, and risk analysis process should be continuously implemented. Each of these phases during the monitoring process is a catalyst for the various activities. For example, information from the risk analysis assists in the modeling of the well formation, in addition, the modeling efforts assists with implementing the monitoring activities.

Future regulations associated with geologic sequestration monitoring and verification would likely solidify this dynamic process in future legislation. Nevertheless, there has not been major legislation to date that has established these forms of requirements. Future carbon capture and sequestration requirements should focus on successfully mitigating GHGs emissions through time but also simultaneously minimizing the regulatory costs associated with the previously presented monitoring processes.

The total cost from the previously presented monitoring process has not been estimated extensively by previous research. In fact the USDOE EIA 1605(b) technical guidelines note the following information:

> "Many options are available to estimate the amount of carbon dioxide that be released from permanent geologic formations over time. Many of these methods are still being tested for effectiveness, uncertainty, and cost."

In turn, the regulatory costs associated with monitoring and verification are very much dependent upon the future requirements and technology options available to track lateral migration of carbon and monitor carbon dioxide leakage outside of the reservoir. The geologic sequestration technology options presented in the USDOE EIA 1605(b) 2006 final technical guidelines include the technologies for the two monitoring activities:

Monitoring techniques for tracking lateral migration of carbon dioxide:

- **Seismic surveys:** 2D, 3D, wellbore-to–surface, and cross-wellbore seismic surveys are sometimes employed in the site characterization process, but can also be effective in identifying the location of the injected carbon dioxide in the reservoir.

- **Gravimetric measurements**: Gravimetric measurements can be used to locate carbon dioxide already injected in the reservoir.

- **Wellhead and formation fluid sampling**: Periodic fluid sampling can be used to verify where the carbon dioxide is in the formation.

Monitoring techniques for tracking carbon dioxide leakage outside the reservoir:

- **Radioisotope tracer monitoring of cement integrity**: The casings of injection wells are known to be the most vulnerable spot for leaks. Periodic measurements of cement integrity with gamma-ray tools have been shown to be effective in detecting and preventing leakage.

- **Seismic surveys**: Repeat 3D (i.e. 4D) seismic surveys can be used to detect leakage out of the reservoir as well as determine the lateral extent of the carbon dioxide in the reservoir.

- **Reservoir pressure monitoring**: Careful logging of reservoir pressures will allow for detection of any carbon dioxide migration outside the injection reservoir. (Note: this technique may not be applicable to storage in saline aquifers.)

- **Establishment of monitoring wells**: Dedicated monitoring wells can be employed for measurement of reservoir pressure and sampling for direct detection of carbon dioxide or tracers.

- **Microseismic monitoring of rock response to injection**: Monitoring of seismic activity during and after injection can predict potential seepage to the atmosphere.

To date, cost estimates have not been published on the monitoring technology options listed above. In turn, the costs of monitoring geologic sequestration projects are uncertain in the future.

4.3 Summary of Regulatory Concerns for Geologic Sequestration

In conclusion to the information presented in Section 4.1 and 4.2 of this document, there are numerous regulatory issues that should be considered by carbon sequestration project developers. For example, there are current regulations surrounding geologic sequestration projects that include: NEPA EIS, USEPA administered SDWA, and state-level drilling requirements. Future regulatory requirements that could develop regarding geologic sequestration projects could potentially include monitoring and verification requirements. The monitoring of GHGs associated with geologic sequestration entails a continual and dynamic quantification process that includes direct quantification of injected carbon dioxide, modeling of the carbon dioxide, and implementation of risk analysis estimating the probability of leakages. In turn, the current and future regulations surrounding geologic sequestration projects could significantly influence the development of these forms of projects.

5. Conclusions

The general objectives of carbon sequestration projects are to store GHGs and to increase the current and future welfare of U.S. citizens. To fulfill this objective, the carbon sequestration project developer must adhere to the current and future regulatory and permitting requirements. This research paper

specifically presents the potential regulatory and permitting requirements that could develop for terrestrial and geologic sequestration projects. The information is relevant given that the regulatory environment surrounding carbon sequestration is uncertain. In addition, future development of geologic sequestration projects could be detoured by these regulatory costs. To present this information, the Augusta research team utilized information gathered from two research projects; Phase I USDA SBIR research project and Phase II SECARB program.

In 2005, the Augusta research team, with funding from the USDA SBIR program, researched the transaction costs associated with on-farm terrestrial sequestration projects and GHG ERTUs development. Specifically, the Augusta research team reviewed the various inputs to commoditize on-farm GHG emissions reductions, including: GHG ERPA negotiation costs, validation, monitoring, and verification requirements for GHG ERTUs. The USDA SBIR also assumed that future GHG ERTUs would be sold in various GHG markets including the CCX, Canadian private market, and the U.S. private market. Therefore, the regulatory requirements observed in this project were dependent on the costs observed in these various programs.

In terms of geologic sequestration, the Augusta research team has begun efforts under Phase II of the SECARB program to assess the regulatory requirements surrounding geologic sequestration projects. In the early SECARB research efforts, permitting and regulatory concerns focused on NEPA, SDWA, and state-level construction and drilling permits. Previous research has not thoroughly assessed these regulatory costs but many of the permitting requirements are observed in the initial years of the field teams.

There are however, additional monitoring and verification requirements that will be observed by geologic sequestration project developers. These activities would include a continuous process of direct underground sequestration carbon dioxide observations, carbon dioxide modeling, and lastly a risk analysis that is implemented to ensure that the likelihood of leakages is minimized. Given that geologic sequestration monitoring and verification technologies are in the development phases, these activities could be costly in the short-run.

5.1 Minimizing Regulatory Costs for Geologic Sequestration Projects

The regulatory costs associated with geologic sequestration projects can be minimized through various policy and technology developments. As previously stated, there is not extensive existing research about these costs for geologic sequestration projects. There are some articles that have been published in Canada and in Europe that discuss the possible technologies and policies that can be used to minimize these costs. For example, Mooney et al. (2002) claims that monitoring services can be implemented on a broad scale to capture the economies of scale phenomenon. Using monitoring services on a large scale for terrestrial sequestration projects has been considered in numerous research articles but has not been examined for geologic sequestration projects. Nevertheless, additional technology options in the field of sensor development and accounting software could be initiated to minimize the administrative costs of extracting and maintaining carbon dioxide data for geologic sequestration projects. In addition, a GHG program can increase the time span between monitoring and verification requirements. This strategy however can lead to a decrease in the integrity of the sequestered carbon. Lastly, governmental entities and non-profit organization can provide for streamlining search and negotiation costs by using an exchange market such as in the case of the CCX.

References:

Chicago Climate Exchange (CCX). 2003. *Chicago Climate Exchange Rulebook*. Chicago: Chicago Climate Exchange Inc, Unpublished

Coase, Ronald, H. 1992. "The Institutions Structure of Production". American Economic Review, 82, issue 4. pp.713-719

Davidson, Jeff and Alfons, Weernsink. 1998. "What Does it Take for a Market to Function". Review of Agricultural Economics. Vol 20, No 2. pp 558-572

Gandee, Jesse. *Economic Feasibility Study of Agricultural Coops as Catalyst in Greenhouse Gas Markets.* Technical Report Submitted to the USDA Cooperative State Research, Education, and Extension Service (CSREES) SBIR Program. January, 2006/

Mooney, Sian., John Antle., Susan Capalbo., and Keith Paustian. "Contract for Soil Carbon Credits: Design". Staff Paper 2002-01, Montana State University, Bozeman Montana. May 2002

Michaelowa, Axel., Marcus Stranzik., Frank Eckermann. and Alistair Hunt. 2003. Transaction cost of the Kyoto Mechanism. *Climate Policy* 3(2003): 261-278.

Wilder, M., M. Willis. and M. Guli. Carbon Contracts, Structuring Transactions: Practical Experiences. 2005. *In Legal Aspects of Implementing the Kyoto Protocol Mechanisms,* ed. by D. Freestone and C. Streck, 295-311. Oxford: Oxford University Press.

Prototype Carbon Fund (PCF). 2003. Creating the Carbon Asset PCF Approached to Additionality, Baselines, Validation, and Verification. http://carbonfinance.org/pcf/Home_Main.cfm (accessed December 21, 2005).

United States. Dept. of Energy (USDOE), Ernest Orlando Lawrence Berkeley National Laboratory. 1999. Guidelines for the Monitoring, Evaluation, Reporting, Verification, and Certification of Forestry Projects for Climate Change Mitigation. Written By Edward Vine et al. http://yosemite.epa.gov/OAR/globalwarming.nsf/UniqueKeyLookup/SHSU5BULJ3/$File/forestry_lbnl_41877.pdf (accessed December 21, 2005).