Insights from “Road Testing” Analyses of Proposed and Existing Greenhouse Gas Offsets Methodologies and Protocols[1]

Background Paper for the EPRI Greenhouse Gas Emissions Offset Policy Dialogue Workshop #6

July 2009

I. Background

This paper has been prepared for a workshop to be held by the Electric Power Research Institute (EPRI) on July 30, 2009 in Washington D.C. It is the sixth in a series of workshops sponsored by EPRI in 2008 and 2009 on the subject of greenhouse gas (GHG) emissions offsets.

The purpose of this paper is to provide background for workshop discussions on the potential supply of domestic offsets in the U.S., on comparisons of different existing offset methodologies and protocols, and on the results of various “road testing” analyses of proposed and existing GHG offset methodologies and protocols that have been completed by U.S. EPA and several other non-profit and scientific research organizations.

Topics addressed in this background paper include:

- Brief overview of “road testing” objectives;
- Road testing analyses of different GHG offset methodologies, protocols and standards for landfills, manure management, and afforestation/reforestation projects prepared by the Stockholm Environmental Institute for U.S. EPA;
- A road testing analysis of GHG offset protocols for afforestation projects prepared by authors from Winrock International and the World Bank’s Carbon Finance Unit;
- Road testing analyses of GHG offset protocols for forest management projects prepared by Duke University environmental policy programs; and
- An analysis of transaction costs for forest management offset projects and impacts on forest management offset potential by Duke University’s Climate Change Policy Partnership.

II. Road Testing Objectives

In recent years, a growing number of methodologies and protocols have been developed to govern the eligibility of various types of GHG offset projects under different offset crediting or registration programs, and to address other considerations in determining the volume of creditable offsets from such projects. Such protocols often have different approaches for such key accounting components as quantifying baseline emissions and project emissions, determining additionality, and addressing leakage and permanence. These disparities suggest the use of different offset protocols for the same project could result in very different volumes of creditable offsets. They also suggest that decisions on various elements of a national GHG offset

[1] Prepared by Natsource Advisory and Research Services and the Electric Power Research Institute.

program likely will significantly impact the volume of offsets that will be available in the U.S. under a future cap-and-trade system.

Road testing efforts have sought to provide a basis for analyzing the impact of using different offset protocols. These efforts involve a detailed quantitative analysis of the volume of creditable offsets a hypothetical offset project would yield under different offset protocols, based on the analyst's interpretation of the protocols and related assumptions in applying offset protocol rules.

This background paper describes road testing analyses undertaken by the Environmental Protection Agency (EPA) and other non-profit and research organizations, and highlights key results and insights relevant to the development of a U.S. offset program under a national-level cap-and-trade program.

III. Road Testing of Landfill Gas, Manure Management and Afforestation/Reforestation Offset Protocols Prepared by the Stockholm Environmental Institute (SEI) for U.S. EPA

In June 2009, the Stockholm Environmental Institute (SEI) published a working paper for the U.S. EPA on the road testing of offset protocols for landfill gas, manure management (i.e., manure digesters), and afforestation/reforestation projects.[2] SEI selected these three project types from among the seven project types addressed in EPA Climate Leaders' offset protocols. The paper road tests two sample projects for each of the three project categories using the following offset protocols, updated as of April 2009:

- EPA's Climate Leaders Program;
- The Kyoto Protocol's Clean Development Mechanism (CDM);
- The Regional Greenhouse Gas Initiative (RGGI);
- The Climate Action Reserve (CAR)[3]; and
- The Chicago Climate Exchange (CCX).

The paper uses unpublished road-testing work undertaken by the Environmental Resource Trust for EPA – and co-authored by Gordon Smith, one of the SEI study co-authors - as a foundation for the analysis.

A wide range of issues are considered in SEI's quantification of creditable offsets from each offset protocol for each project. These include, but are not limited to, differences in definitions of the applicable project type (e.g., with respect to location, technology or size); what emissions and sources are included within the project boundary; whether and how to account for leakage;

[2] "Road-Testing of Selected Offset Protocols and Standards – A Comparison of Offset Protocols: Landfills, Manure, and Afforestation/Reforestation," June 2009, Michael Lazarus, Gordon Smith (Stockholm Environment Institute (SEI)), and Kimberly Todd, Melissa Weitz (U.S. EPA Work Assignment Managers), Working Paper WP-U.S.0904, http://www.sei-us.org/WorkingPapers/WorkingPaperUS09-04.pdf
[3] In 2009, the California Climate Action Registry (CCAR) changed its name to the Climate Action Reserve (CAR). Throughout this paper we will refer to this organization as the Climate Action Reserve (CAR).

requirements for emissions monitoring; whether there are differing regulatory eligibility screens; how additionality is addressed; and how baseline emissions are calculated.

A. Landfill projects

Landfill gas offset projects are considered to have well-developed methods for accounting. However, there is still potential for fairly significant differences in creditable offset volumes from a given project depending on the offset protocol that is used. In its study, SEI considered two sample landfill projects. The first project is a landfill gas-to-energy project with three generator sets totaling over 5 MW, in which an electric company agrees to purchase electricity and associated Renewable Energy Credits (RECs). It has been validated by a third party and project documentation shows the gas collection and destruction system was installed to reduce emissions. While the landfill is subject to New Source Performance Standard (NSPS) rules, its emissions are lower than the threshold rate at which NSPS would require installation of a gas collection and control system. The second project is identical to the first, except that a pre-existing gas collection and destruction system was already capturing some methane prior to project implementation, which reduced the volume of creditable offsets from the project.

After confirming the eligibility of these projects under the different protocols, and considering related issues, SEI provided quantified estimates of creditable reductions. For project #1, RGGI, CCX and CDM protocols produced nearly identical estimates of expected offset volumes. CAR and Climate Leaders credit 15-20% less than the other protocols due to a 10% soil oxidation factor and deductions for project emissions associated with fossil fuel use and non-combusted methane. In light of the common perception that landfill projects are straightforward, the 15-20% difference in offsets credited by CAR and Climate Leaders is noteworthy. The disparity would be smaller if the project used flares or boilers, which have more complete combustion. However, if flares were used, CDM would discount reductions between 10% (for closed, unmonitored flares) to 50% (for open flares).

Project #2 results differ more significantly because CCX, Climate Leaders and RGGI do not account for reductions from pre-existing collection and destruction systems, and therefore overestimate project emission reductions. CAR estimates zero emission reductions from the project (versus roughly 130,000-150,000 tons[4] for the other non-CDM protocols) because it assumes zero emissions in the baseline, based on the assumption that the pre-existing system would have combusted collected methane up to its maximum capacity. Thus, this project would not be undertaken under CAR or a federal offsets program that used the CAR protocol. CDM estimates approximately 60,000 tons of reductions because it recognizes additional reductions from the project beyond those from the pre-existing system.

B. Manure management projects

For manure management projects, project parameters such as animal type and baseline management practices can vary significantly. Given the heterogeneity of these projects, and differences among protocols, different protocols may be expected to yield very different results. SEI also cautions that for these projects, the specific characteristics of sample projects can vary significantly from the range of actual practices. SEI's first sample manure project is a 550 dairy

[4] In this background paper, tons refer to metric tons carbon dioxide-equivalent (CO_2e).

cow operation in New York State which installed a conventional anaerobic digester in June 1998, three years after entering into operation. In the baseline prior to digester installation, manure was pumped to a lagoon. From April to October it was trucked to and spread in nearby fields. From November to March, it was stored as a liquid/slurry on site. The digester was installed for odor reduction and to reduce manure transport. Biogas from the digester is utilized to generate electricity and heat. The second manure project is a long-standing 695 dairy cow operation in Western Washington which installed an anaerobic digester in 2004. Prior to digester installation, manure was separated into solid and liquid streams. The liquids were stored in an anaerobic lagoon from November to February and applied to fields from March to October. Biogas generated from the digester is used to generate electricity and heat for on-site use.

All of the manure management protocols credit emissions reduction from the destruction of methane regardless of the ultimate use for energy. The SEI study does not consider crediting for emission reductions resulting from fossil fuel use displacement through the end use of collected methane, which in any case is only credited under CDM's manure management methodology and Climate Leaders' separate protocol for end use of methane.

Differences in eligibility requirements among protocols include restrictions on eligible livestock types (CDM and Climate Leaders), a requirement that baseline manure management practices resulted in significant methane emissions (RGGI, CCX, CDM), and air and water standards for projects (CAR, CDM). Under Climate Leaders, RGGI and CAR, the digester installation must exceed common practice, as defined by each protocol's slightly different performance standards. CCX has no performance standard or additionality requirement beyond its eligibility requirement, while CDM has a project-specific additionality test with requirements for investment and barrier analysis.

Differences between the different protocols' approaches to calculating baselines and emission reductions are numerous, and lead to significant differences in estimates of expected offset volume. For example, in project #1, estimated baseline emissions ranged from 308 tons (CCX) to 466 tons (RGGI). Estimates of project-related emissions varied even more significantly, from 0 (RGGI and CCX) to as much as 1,145 tons (CDM) (other estimates were 131 tons (Climate Leaders) and 805 tons (CAR). The largest contributor to variation in results was estimated project emissions from the biogas system – this ranged from zero (RGGI and CCX) to as much as 923 tons (CDM) (other estimates were 75 tons (Climate Leaders) and 732 tons (CAR)). CAR and CDM require that methane emissions from the biogas control system be based on verified project values, or that a default value of 85% capture be used. This differed from Climate Leaders, for example, which assigned a collection efficiency of 99% for the plug-flow digesters used. Many other differences in baseline and emission reduction calculations are summarized in the paper, and contributed to offset volumes ranging from zero (CAR and CDM) to as high as 466 tons (RGGI) (other estimates were 198 tons (Climate Leaders) and 309 tons (CCX)). Under CAR and CDM, project #1 would not have been undertaken.

Similarly, for project #2, CAR and CDM estimated zero reductions. Other protocols estimated reductions of 556 tons (CCX), 650 tons (RGGI), and 776 tons (Climate Leaders). For this project, CAR's and CDM's measurement of emissions from the biogas control system again played a significant role. In addition, only CAR and CDM estimate digester effluent emissions in the project case, and CAR’s approach in particular led to a high project emissions estimate. (Interestingly, SEI recommends that Climate Leaders’ protocol be revised to take digester effluent emissions into account; in the case of project #2, this likely would have led to a zero-emission-reductions estimate from Climate Leaders.) Lastly, only Climate Leaders and CDM account for leakage, and CDM estimated significant leakage associated with methane and N_2O emissions from land application of manure (although even without leakage CDM would have estimated zero reductions from the project).

C. Afforestation and reforestation projects

As noted in the SEI report, afforestation and reforestation (A/R), together with forest management, are considered to be the largest potential sources of domestic offsets in the U.S., but the volumes of offsets these types of projects will generate will depend significantly on protocol elements, as well as other factors such as non-forestry demands for land and the market price of carbon.

A/R Project #1 restores degraded forest land in the dry interior Pacific Northwest. It involves removing or reducing cattle and restoring Ponderosa Pine throughout the project area. The project was started ten years ago. Actual measurements are extrapolated to estimate tree sizes and density in year 50 of the project at which point cumulative offsets are calculated. The project includes no harvesting because a clear-cut normally would occur after 50 years on the site.

A/R Project #2 converts agricultural land into a pine plantation in the Southeast through staggered planting and intensive forest management, with clear-cut harvesting every 20 years on each parcel, staggered each year consistent with staggered planting. Tree growth and yield are based on values from an actual property located in northern Florida. Cumulative offsets are calculated at year 40.

Estimates of cumulative offsets from A/R Project #1 ranged from 18,158 tons (CDM) to 18,874 tons (CAR) to 20,711 tons (CCX), to 21,404 tons (RGGI) to 25,263 tons (Climate Leaders). Climate Leaders also estimated the highest level of creditable offsets from A/R Project #2 (1,328 tons). Other estimates were 719 tons (CAR), 881 tons (CDM), 903 tons (RGGI), and 1,253 tons (CCX).

Unlike the manure and landfill project examples, there is no consideration that completely negates all offset value for either of the two A/R projects. Growth of live trees is the main driver of the volume of offsets. CAR’s risk discount (a project-specific, calculated assessment of the risk of reversal of sequestration) was the second-largest driver of differences. In particular, Project #2’s risk rating was impacted by the risk that the land would be developed in the future. As a result, 36.25% of net sequestration was set aside in an insurance buffer and could not be counted as offsets. CAR’s leakage methodology in Project #2 led to a reduction of 430 tons (37% of CAR’s total if leakage hadn’t been counted), versus zero for other categories. Although this point was not emphasized in the report, the set of carbon pools counted in each protocol appears to have a significant impact as well. CAR is the most comprehensive protocol in terms of required pools, followed by Climate Leaders (which excludes harvested wood products), and others (which omit or make optional the inclusion of several other carbon pools).

SEI points out that uncertainty provisions in certain A/R protocols may create high transaction costs and significantly reduce the volume of offsets from A/R projects. For example, RGGI requires that each carbon pool (even small pools) be measured separately and with no more than 10% uncertainty with 95% statistical confidence. In the authors' view, this makes sampling more expensive than necessary to achieve accurate estimates. CAR requires that all verification personnel be individually certified by ANSI. This requirement increases costs for verifiers, leading many to drop out and the rest to charge higher verification fees.

The authors also recommend wood products be excluded from offset accounting, because wood product harvests occur under business-as-usual forest management. As noted in the paper, "Wood products are generally not owned or controlled by the landowner and there is risk of double counting wood products if wood products are counted both at interment at landfills and at production."

IV. Road Testing of Other Offset Standards, Process Guides and Initiatives by SEI for EPA

In addition to its analysis of offset protocols, SEI undertook an analysis for EPA comparing Climate Leaders with other offset standards, initiatives, process guides and recommendations – specifically, the Voluntary Carbon Standard (VCS), Gold Standard (GS), the Offsets Quality Initiative (OQI), and the International Standards Organization (ISO).[5] A brief selection of highlights from the study follows.

VCS and Gold Standard are complete offset standards which include accounting standards, monitoring, verification and certification standards, and registration and enforcement systems. ISO is a process guide for offset projects and protocols and can be used in conjunction with other standards and offset programs. OQI provides a set of general recommendations about how to ensure high quality offsets. In contrast to other standards, Climate Leaders uses only its own protocols. VCS and Gold Standard rely mainly on CDM and/or CAR for their protocols.

With respect to additionality, VCS and Gold Standard use the CDM additionality tool and their own tests to assess additionality. OQI recommends an approach that has both project-specific and standardized elements. Only Climate Leaders relies exclusively on performance-based additionality assessment. Particularly for project types with significant business-as-usual activity, such as agricultural soil management, SEI recommends that Climate Leaders clarify its criteria for setting performance-based or practice-based additionality thresholds.

[5] "Updated Road-Testing of Climate Leaders' Offset Methodologies: Landfills, Manure, and Afforestation/Reforestation: A Comparison of Carbon Offset Standards," Anja Kollmuss, Michael Lazarus, Carrie Lee (Stockholm Environment Institute), U.S. EPA Work Assignment Managers: Melissa Weitz and Kimberly Todd, Project Manager: Heidi Nelson-Ries, Stratus Consulting, Inc., June 2009.

Gold Standard and VCS provide specific guidelines for addressing permanence and leakage. In contrast, while Climate Leaders requires, and OQI recommends, that these issues be accounted for, they do not offer specific guidelines or requirements. SEI recommends that Climate Leaders provide such guidance. ISO 14064 provides only general neutral guidelines on this topic.

Lastly, regarding verification, VCS and Gold Standard require third-party validation, while Climate Leaders recommends, but does not require third-party validation or verification. SEI recommends that Climate Leaders institute such a requirement. Similarly, ISO 14064 and OQI do not specify validation requirements.

V. Road Testing of Afforestation Offset Protocols by Winrock International and the World Bank

In October 2008, authors from Winrock International and the World Bank's Carbon Finance Unit published a road testing analysis focused on afforestation protocols.[6] The study assesses and compares creditable offset volumes that could be generated from a typical, hypothetical afforestation pilot project using offset protocols defined in the U.S. Department of Energy's 1605(b) Technical Guidelines for Voluntary Reporting of Greenhouse Gases (i.e., the 1605(b) program), CCX, RGGI and CAR. The pilot project involved afforestation of grazing lands in Shasta County, California – a common activity that is allowed under each of the protocols. After shrub vegetation was cleared from the site, a mix of ponderosa pine, sugar pine and Douglas fir was planted over 285 hectares. The stand was thinned at year ten to reduce stocking levels to approximately 60 trees per hectare. The baseline for the project is continued use as a grazed rangeland. Winrock International, which has done significant work analyzing such projects in California, used its experience to estimate the actual amount of sequestration that occurred in the project, and then compared that amount to the creditable offsets it estimated for the project based on each protocol.

The authors note that only RGGI and CAR require projects to demonstrate regulatory additionality. All of the protocols analyzed address permanence either by requiring legal easements or indefinite reporting for offset projects to remain registered. In the authors' view, leakage is poorly addressed in all four protocols.

Actual sequestration from the project, net of baseline emissions, was estimated to be 312,685 tons CO_2 in year 60 of the project. Based on the protocols considered, the amount of creditable offsets ranged from 118,044 (CCX entity-level accounting[7]) to 260,983 tons (CCX project-level accounting and RGGI) to 288,050 tons (CAR) to 299,857 tons (1605(b)). Thus, 1605(b)'s result came closest to the actual level of sequestration from the project.

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[6] "Comparison of registry methodologies for reporting carbon benefits for afforestation projects in the United States," Timothy R.H. Pearson, Sandra Brown (Winrock International), Kenneth Andrasko (World Bank/Carbon Finance Unit), *Environmental Science and Policy* 11 (October 2008), 490-504.

[7] CCX's entity-level accounting protocol applies to projects that occur on the lands of an entity covered under a cap and trade system. CCX's project protocol applies to projects not located on the lands of such an entity. In practice, it may be unlikely that a U.S. federal level cap-and-trade program would have different protocols for projects depending on whether the landowner is a covered entity under the program or not.

The authors highlighted several factors that contributed to these divergent results. Unlike other protocols, the CCX entity-level protocol limits measurement to the stem of the tree. It also does not include any measurement pools other than sequestration in trees aboveground. This leads to creditable offsets that are over 50% lower than any other protocol. On the other end of the spectrum, 1605(b) includes all measurement pools, and is the only protocol to do so. CCX, CAR and RGGI omit understory (shrubs and grasses) emissions from the baseline and the project, thereby over-crediting reductions from the project by approximately 15,000 tons (or roughly 5% of actual net sequestration of 312,685 tons from the project). The use of look-up tables under 1605(b) reduces field measurement costs but leads to over-reporting of stocks in dead wood, litter, soil and understory of 21,569 tons (6.9% of actual net sequestration). The authors also note that CAR's uncertainty deductions reduce its total by 27,238 tons after 60 years (8.7% of actual net sequestration).

CAR, RGGI and CCX prescribe certain measurement pools, which may increase costs for landowners unnecessarily (e.g., if a project does not lead to significant changes in those measurement pools). On the other hand, landowners can leave out some pools, and therefore can select whichever categories maximize the amount of creditable offsets. While 1605(b) is the only protocol that includes all measurement pools, it uses a static rather than a dynamic baseline, which can lead to inaccuracies in cases where the baseline changes over time. In addition, it does not ensure that uncertainty is addressed in any precise way. RGGI, on the other hand, requires each selected pools to be measured at 95% confidence intervals equal to 10% of the mean or less. This stringent requirement increases costs and creates a disincentive to measure optional pools. For example, including soil carbon increases monitoring costs by 15-26% over including aboveground carbon only. Similarly, CAR requires precision of approximately 5% of the sample mean with 90% confidence. This requirement increases costs by 20% relative to the cost of attaining a precision of approximately 10% of the mean with 95% confidence.

Like the CDM, RGGI limits projects to three 20-year crediting periods, even though RGGI requires a permanent easement that precludes cutting down trees after year 60. CAR, CCX and 1605(b) do not limit the duration of projects, and can claim sequestration after 60 years. The next 40 years would result in an additional 55,643 tons for CAR, 76,664 tons for 1605(b), and 33,829 tons for CCX.

In order to place these findings at the project level in a broader perspective, the authors estimated creditable offsets from a portfolio of 1000 projects like the pilot project. They note that such a program

> "…could record 2.5 times as many metric tons under the 1605(b) protocol guidelines as under the more conservative CCX guidance, a difference of 182 Mt CO2-e above the CCX entity accounting estimate. A program under CAR or RGGI would record 2.2 times the number of credits as under the CCX entity accounting protocols."[8]

[8] "Comparison of registry methodologies for reporting carbon benefits for afforestation projects in the United States," Pearson et al., op, cit. p. 501.

The study concludes that the 1605(b) protocol is most favorable to landowners/project developers, as it yields the highest level of creditable offsets and allows for limited measurement costs. It also comes closest to the authors' estimates of actual sequestration. However, it does not require 3rd party auditing, which, the authors note, creates the possibility of gaming. In addition, 1605(b) is a voluntary mechanism, and does not have the credibility of CAR and RGGI, which have more stringent requirements. In the authors' view, an ideal protocol would

> "…require proof of financial and legal additionality, and would fully consider leakage and all project emissions. However, an ideal protocol would also seek to minimize project implementation costs for landowners while maintaining accurate and precise estimates of GHG impacts. To do so, an ideal protocol would allow projects to achieve the given precision standard across all pools and would allow pools to be included or excluded at the projects' choice as long as doing so did not artificially inflate the reported impacts."[9]

VI. Road Testing of Forest Management Protocols by Duke University Environmental Policy Programs

In October 2008, a group of authors associated with environmental policy programs and institutes at Duke University published a road testing analysis of forest management offset protocols.[10,11] As noted in the study, forest management accounting methodologies are still in the early stages of development, and "are complicated by the dynamic nature of carbon storage in forest systems and a lack of standardized management and land use practices across users and landscapes." The report undertook a "virtual field test" and compared results for seven forest management offset protocols:

1) The Department of Energy's 1605(b) voluntary program;
2) The Georgia Forestry Commission (GFC) Carbon Sequestration Registry Protocol;
3) CCX's Sustainably Managed Forests/Long-Lived Wood Products Protocols;
4) CAR's Forest Project Protocol;
5) The Voluntary Carbon Standard (VCS) Improved Forest Management Protocol;

[9] Ibid, p. 503.
[10] "A Critical Comparison and Virtual "Field Test" of Forest Management Carbon Offset Protocols," Christopher S. Galik (Climate Change Policy Partnership, Duke University), Daniel deB. Richter, Megan L. Mobley (Nicholas School of the Environment and University Program in Ecology, Duke University), Lydia P. Olander, Brian C. Murray (Nicholas Institute for Environmental Policy Solutions), October 2008, http://www.nicholas.duke.edu/institute/ccppoffsets.pdf
[11] Three of the authors of the study prepared an article in 2009 (pending publication) which summarizes the prior study. It also provides a few additional details and findings (e.g., with respect to break-even carbon prices for the project that is road tested under different offset protocols) which are cited where appropriate in this section of the background paper. "A virtual "field test" of forest management carbon offset protocols: the influence of accounting," Christopher S. Galik (Climate Change Policy Partnership, Duke University), Megan L. Mobley, and Daniel deB. Richter (Nicholas School of the Environment and University Program in Ecology, Duke University), 2009 (pending publication).

6) A forest management protocol derived from recommended concepts and provisions in Duke University's *Harnessing Farms and Forests in the Low-Carbon Economy* (HFF); and

7) A draft recommendation for active forest management offset projects proposed by the State of Maine for inclusion under the Regional Greenhouse Gas Initiative (RGGI).

The hypothetical forest management project is in the Calhoun Experimental Forest in the Piedmont region of South Carolina, and uses the forest carbon database for that forest, which incorporates five decades of in-field measurement and monitoring of carbon sequestration of Southeastern loblolly pine stands. A spreadsheet model simulated repeated 25- and 50-year clear-cut harvests at the Calhoun forest, allowing for estimation of carbon sequestration over 100 years of project implementation. As described in the report,

> "The project consists of ten 10-hectare, even-aged stands of identical composition and site quality… and is implemented for a period of 100 years. At project inception, there are two stands each of 0, 5, 10, 15, and 20 years old. One stand in each pair is managed on a 25-year rotation until the first harvest, and then converted to a 50-year rotation. The other stand in each pair is immediately converted to a 50-year rotation. In this manner, the rotation extension is phased in over time, yielding a more consistent harvest stream."[12]

The authors make a distinction between 1605(b) and the GFC Protocol – which are classified as "registries" because they provide guidance on carbon accounting and creating a system for registering carbon sequestration – and the other protocols considered in the study, which are considered "full protocols" because they are designed with the goal of being able to create and sell offsets. This context may help explain why 1605(b) and the GFC Protocol do not require deductions for leakage or uncertainty. Consequently, these protocols estimate higher levels of creditable offsets. For this reason, the study evaluates these protocols separately to allow for comparison with the "full protocols."

Results of the "field test," or road test, were as follows. Over the life of the project, 1605(b) yields creditable offsets of 59,798 tons. This is over twice the amount estimated for any full protocol, and is nearly an order of magnitude greater than the amount calculated for the VCS. The GFC Protocol yields 39,633 tons if all carbon pools eligible for inclusion under that protocol were considered, and 17,964 tons if only required pools were included in the accounting. These estimates reflect a number of assumptions, including an assumption that credits are bought back from the market in years of negative sequestration.

Among the full protocols, CCX has the highest amount of creditable carbon when all eligible carbon pools are considered – 27,995 tons (all pools). CCX has a number of optional pools, and yields a much lower amount of credits when only required pools are considered -- 11,497 tons. RGGI yields the next-largest amount of credits for all pools – 17,346 tons. Like CCX, some carbon pools are optional in RGGI. When only required pools are considered, RGGI yields

[12] "A Critical Comparison and Virtual "Field Test" of Forest Management Carbon Offset Protocols," Galik et al., October 2008, op. cit.

11,207 tons. CAR yielded 17,138 tons and Duke University's protocol (HFF) yielded 13,247 tons (all pools are required for each). VCS yielded the lowest estimates – 7,837 tons for all pools, and 7,057 tons for required pools.[13]

The authors find a number of reasons for differences in creditable offsets from each protocol. Many (five out of six) carbon pools are optional for VCS, and are optional or not eligible for RGGI (there are 4 eligible pools, 2 of which are optional). This limits the total amount of crediting possible under these protocols. In contrast, all 6 pools are required for 1605(b), and Duke University's HFF protocol requires that 5 of 6 eligible pools be measured. However, HFF's creditable offsets are reduced by its aggressive baseline. HFF uses a cohort group performance standard that uses regional trends and data to determine the baseline level of carbon storage, and was found to be the most conservative approach (i.e., it results in the lowest amount of offset crediting) when all non-baseline accounting components were held constant across scenarios. This approach credits only the portion of sequestration that is beyond the BAU management scenario. In the case of the hypothetical project, crediting does not start under a cohort baseline approach until approximately year 19, when projects surpass average regional stocking levels. The authors note that while the cohort approach avoids the gaming that can be encouraged under other baseline approaches, it does not account for differences in site quality between the project and the applicable regional average, which may over- or under-estimate project sequestration levels. It also relies on outside data, which may not be available.

In contrast, 1605(b), GFC, CCX, and to certain extent, RGGI, use a base-year approach which assumes that all (or for RGGI, a portion) of carbon sequestered above an initial inventory is additional. This approach allows the most carbon to be credited, and allows for the earliest crediting of carbon. The authors of the study note that this approach has the advantage of being straightforward, but can result in the crediting of non-additional carbon depending on the pools included and the timing of the project. For example, 1605(b) would estimate creditable offsets of over 500 tons over the life of the project for continuation of BAU management (i.e., 25-year harvests, while GFC would credit 77 tons and CCX 49 tons. RGGI's approach involves some adjustment of the baseline and discount rates for crediting depending on how sequestration on the site relates to an average level. The authors believe that this manner of attempting to improve upon a base-year approach is somewhat arbitrary and is prone to gaming.

CAR and VCS opt for a third baseline approach – a single practice performance standard – in which the landowner defines the BAU scenario and credit is received only for sequestration beyond the BAU scenario. The authors note that since the BAU management scenario can never be known for certain and can vary significantly, the choice of BAU scenario is subjective and can lead to crediting of non-additional tons.

Differing approaches for addressing leakage have a strong impact on volumes of creditable offsets. As of the time of the study, CAR only encouraged, but did not require, quantification of off-site leakage. RGGI includes requirements to guard against leakage, but as of the time of the

[13] In addition to these base case values (i.e., best estimates) in the 2008 report, the subsequent article ("A virtual "field test" of forest management carbon offset protocols: the influence of accounting," Galik et al., 2009 (pending publication)) includes a graph with low- and high-carbon case estimates. These cases incorporate assumptions regarding how different protocols are applied that generate the lowest and highest amounts of carbon, respectively.

study had not yet developed a process for determining leakage. The two protocols that require quantification of leakage and provide guidelines for doing so are VCS and HFF. VCS' leakage calculation results in a deduction of 10% of annual creditable carbon, while HFF's calculation yields a much larger deduction of 43%. The authors note that the accuracy of such estimates may be improved through the use of national models or assessments to estimate system-wide leakage.

Approaches for addressing permanence vary as well. GFC recommends, and CAR and RGGI require, conservation easements or long-term legal agreements. CCX, VCS and RGGI require the establishment of a buffer of reserve credits. The study notes that VCS allows a project to draw down its buffer holdings if its risk rating remains the same or is reduced, and that RGGI is considering adopting such an approach. This approach provides incentives for landowners to improve their risk rating. Related adjustments can be important for total creditable offset volumes. If the RGGI withholding amounts were reduced from 20% to 0%, this would reduce the amount of tons withheld by approximately 1,500 tons over the life of the project, or approximately 9% of total credited offsets.

Depending on the protocol, inclusion of wood products in project carbon accounting can have important implications for results. To estimate offsets for wood products, the amount of carbon in harvested wood is multiplied by the fraction expected to remain in use or in landfills for 100 years.[14] In the case of the hypothetical project, inclusion of wood products actually reduces creditable carbon from the project, because wood product generation in the BAU scenario is higher than in the project -- the baseline assumes harvests every 25 years, while the project uses a 50-year rotation. This dynamic has the strongest impact on total net sequestration under VCS, which has the lowest overall level of crediting for any protocol.

The study also provides preliminary estimates of break-even carbon prices for forest management projects. These are discussed in greater detail in the sections that follow.

Lastly, the authors highlight that CCX and CAR employ a sliding scale for deductions associated with different levels of uncertainty, and express the view that this flexible approach "allows a landowner to choose the best fit of discount and administrative burden while still guaranteeing a minimum level of data quality." They believe such an approach may have advantages over a "flat certainty requirement" which can increase implementation costs and provide disincentives for including carbon pools subject to greater uncertainty.

A. Break-even carbon prices for forest management

One set of estimates in the authors' article that is pending publication -- break-even carbon prices for the hypothetical project based on the amount of creditable offsets yielded by each protocol -- has particularly important implications for U.S. domestic offset supply. (Note that these break-even estimates are higher than others that Duke University has prepared more recently, and which are discussed below in Section VII.) Price ranges are estimated for low- and high-carbon case estimates, which incorporate assumptions regarding how different protocols are applied that generate the lowest and highest amounts of carbon, respectively. Under the "all eligible pools"

[14] "A virtual "field test" of forest management carbon offset protocols: the influence of accounting," Galik et al., 2009 (pending publication).

scenario, the authors estimate that the break-even carbon price for the project would be approximately $13/ton under 1605(b), $20/ton under GFC, $25-30/ton under CCX, $35-50 under CAR, $40-50 under RGGI, $45-$160 under VCS, and $100-200 under HFF.[15] Estimates for the "only required pools" scenario are slightly higher for some protocols and much higher (over $200) for the upper-bound VCS estimate. Thus, if only "full protocols" are considered, carbon prices would need to be anywhere from $25-$200/ton for forest management projects to be undertaken. In the authors' view, the results may suggest that "forest management offset projects, especially those increasing carbon storage by extending rotations, may require higher carbon prices to be financially feasible than previously estimated." They also cite another recent study (Sohngen and Brown, 2008) which found similar results.[16]

While the authors point out that their break-even estimates fall within the range of national assessments undertaken by EPA in 2005, they differ significantly from implied break-even estimates in EPA's modeling of the Waxman-Markey discussion draft in April 2009. In EPA's report, it estimated that forest management would account for approximately three-quarters of the total U.S. domestic supply of offsets in 2015 at a domestic offset price of $11-14/ton CO_2, and approximately two-thirds of the domestic offset supply in 2020 at an offset price of $14-18.[17,18] (Afforestation is assumed to account for most of the remaining domestic offset supply.) A more recent analysis by EPA of the Waxman-Markey bill as approved by the Energy and Commerce Committee shows similar offset price estimates ($13 in 2015, $16 in 2020). It is important to highlight that if the Duke University authors' break-even carbon price estimates are representative of actual average break-even prices for these projects, and if market prices for offsets are not significantly higher than those estimated by EPA, forest management may not be the significant source of offsets that EPA expects.

The authors caution that a comparison of relative break-even prices across protocols is potentially more informative than the specific price estimates themselves. A number of factors lead to high prices in this study, such as the specific project considered (a doubling of rotation length, which requires higher break-even carbon prices than other eligible forest management projects), the small size of the project (larger projects have lower break-even prices, although the difference is not dramatic), and the "worst-case" assumptions employed in the "high-carbon" case. In addition, the project reflects only one type of forest, and may not be representative for all projects in the country as a whole. As discussed below, a more recent analysis by Duke University has revisited these estimates in a more comprehensive analysis of transaction costs.

[15] Ibid. Note that all figures cited are approximate and based on a graph that did not display precise data points.
[16] Sohngen, B., Brown, S. (2008), "Extending timber rotations: carbon and cost implications," *Climate Policy* 8: 435–451.
[17] "EPA Preliminary Analysis of the Waxman-Markey Discussion Draft – Appendix," EPA, April 20, 2009, p. 60 (offset graph) and "EPA Preliminary Analysis of the Waxman-Markey Discussion Draft," EPA, April 20, 2009, p. 18 (offset prices).
[18] A more recent analysis by EPA of the Waxman-Markey bill as approved by the Energy and Commerce Committee shows similar offset price estimates ($13 in 2015, $16 in 2020.) "EPA Analysis of the American Clean Energy and Security Act of 2009 H.R. 2454 in the 111th Congress," June 23, 2009, p. 14.

VI. Analysis of Transaction Costs for Forest Management Projects by Duke University's Climate Change Policy Partnership

As a follow-up to Duke University's road testing analysis of forest management offset project protocols, the university's Climate Change Policy Partnership has developed a working paper analyzing transaction costs for different forest project types, with the objective of informing estimates of U.S. offset supply from these project categories.[19] In the authors' view, transaction costs will be a key challenge that may constrain the supply of forest carbon offsets because most U.S. forestlands are in privately-held small land holdings. The analysis uses the same hypothetical project type as the previous study – a 100-year-long rotation extension project conducted across 10 stands of equal size. However, it extends the forest database used in the previous study to include 46 separate regional forest types and associated BAU rotations, to consider differently-sized projects, and to estimate associated transaction costs (defined in the study as costs associated with project implementation). It considers the following six protocols: 1605(b), GFC (the Georgia Forestry Commission Carbon Sequestration Registry Project Protocol), CCX, CAR version 2.1 (previously approved), CAR version 3.0 (currently pending approval), and VCS.

For all projects, including a BAU, timber-only baseline scenario, the study estimates a full range of start-up costs, on-going implementation costs, and carbon project development fees, which include consulting fees, scoping fees, planning, project documentation and process determination. It generally assumes that aggregators are not required for forest projects, and therefore assigns no aggregation fee (although the potential impact of aggregation is considered separately). Then, for the project scenario, the study assigns costs for required activities under each of the protocols to estimate total costs, including carbon-related transaction costs, based on an assessment of requirements under each protocol, project-related reports and the authors' market research. Requirements and fees under the various protocols include but are not limited to analysis of project risk, leakage and social impacts; third-party verification; site-specific sampling for baseline determination and monitoring, measurement and reporting of project sequestration; registration fees; annual desk audits; field verification; trading fees; and registry maintenance fees. Additional details on how costs are assigned to different protocols, and different values and assumptions used in the calculations, are provided in the study.

Based on calculations of transaction costs, the study calculates the break-even carbon prices at which the project (in the Calhoun Experimental Forest in South Carolina) can achieve positive net returns. These are summarized in the figures below (reproduced from the study).

[19] Working paper, Christopher S. Galik, Justin S. Baker, Joseph L. Grinnell, Climate Change Policy Partnership, Duke University, Spring 2009

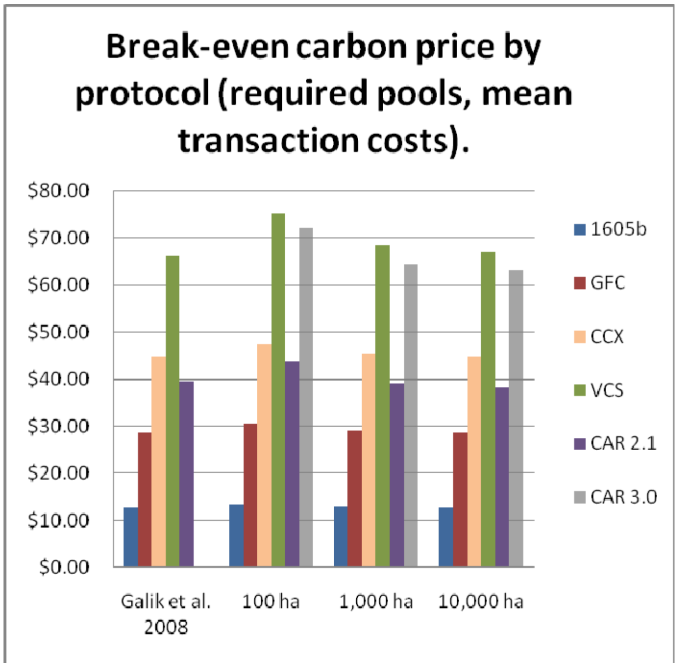

Figure 1 (reproduced from "Working Paper," Christopher S. Galik, Justin S. Baker, Joseph L. Grinnell, Climate Change Policy Partnership, Duke University, Spring 2009, pending publication). Break-even carbon price by protocol ($/metric ton CO_2e), considering only required pools for a doubling of rotation length for the Calhoun Experimental Forest data set (25 to 50 years). Values calculated in "A Critical Comparison and Virtual "Field Test" of Forest Management Carbon Offset Protocols," Galik, et al., October 2008, op. cit. are included as a reference.

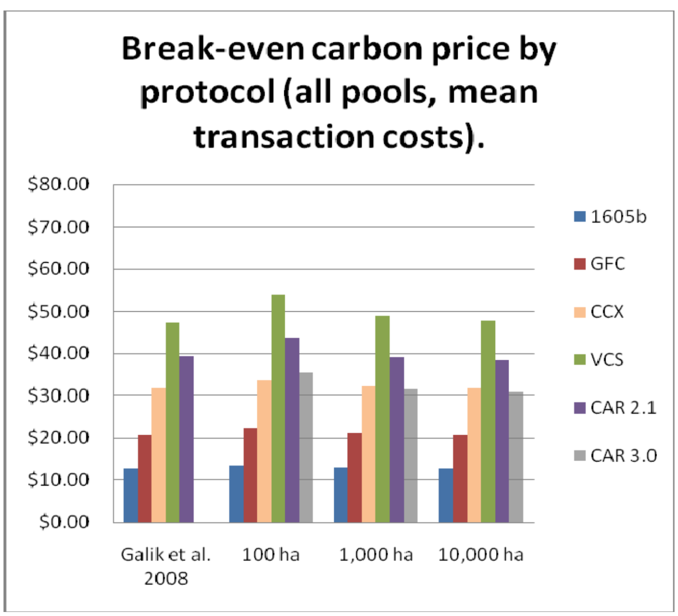

Figure 2 (reproduced from "Working Paper," Christopher S. Galik, Justin S. Baker, Joseph L. Grinnell, Climate Change Policy Partnership, Duke University, Spring 2009, pending publication). Break-even carbon price by protocol ($/metric ton CO_2e), considering all pools for a doubling of rotation length for the Calhoun Experimental Forest data set (25 to 50 years).

As shown in figures 1 and 2, the VCS has the highest break-even prices when only required pools are considered (Figure 1). VCS' break-even prices range from approximately $67/ton for a large (10,000-hectare) project to approximately $75/ton for a small (100-hectare) project. CAR's prices are nearly as high as VCS', and are followed by CCX, CAR 2.1, GFC and 1605(b). For a 100-hectare project, the break-even price for VCS ($75) is approximately five times higher than the break-even price for 1605(b) ($13). CAR 2.1 has the lowest prices for any full protocol – approximately $38/ton for a large project and $43/ton for a small project. Prices under each protocol are slightly lower for larger projects.

When all carbon pools are considered (Figure 2), VCS again has the highest break-even prices. In this scenario, CAR 2.1 has the second-highest price, followed by CCX, CAR 3.0, GFC and 1605(b). Prices for VCS range from approximately $48/ton for a large (10,000-hectare) project to approximately $53/ton for a small (100-hectare) project. CAR 3.0 has the lowest prices for any full protocol – approximately $30/ton for a large project and $35/ton for a small project. Prices under each protocol are slightly lower for larger projects.

For comparison purposes, the authors include in the figures a range of prices estimated for the 2008 Duke University report.[20] These estimates are approximately 4 to 12 percent lower than the more recent estimates for a comparable 100-hectare project, depending on the protocol. The authors note that the most-recently-updated prices reflect a much more comprehensive assessment of transaction costs, but that the impact of including these costs is dampened by their inclusion in both the baseline BAU case and the project case.

The prices in the figures do not include the significantly higher upper-bound prices estimated for Duke University's 2009 article. As discussed in Section VI.A., these upper-bound prices were driven by the worst-case, high-cost assumptions in the "high-carbon" scenario. While the prices in this most recent study are lower, it is important to highlight that they are in most cases significantly higher than EPA's estimates of offset prices under the Waxman-Markey bill in 2015 and 2020 – the only exceptions being prices for 1605(b) (approximately $13/ton for project sizes and both carbon pool scenarios) and GFC (approximately $20/ton for all project sizes in the "all pools" scenario). Thus, as noted earlier, it appears that carbon prices under a future U.S. cap-and-trade system will need to be higher than estimated by EPA if forest management is to account for a significant share of offset supply in early years of the cap-and-trade program.[21]

The study's estimates of transaction costs by protocol and project-size show that CAR version 2.1 (version 3.0 data was not included in this comparison) has the highest transaction costs, followed by CCX or VCS depending on the size of the project, then GFC and 1605(b). Transaction costs per acre decline dramatically with the size of the project "because certain fixed costs (e.g., travel and, in some cases, administrative fees) remain constant while variable costs decrease per unit area for larger projects." For example, CAR's transaction prices are $20/hectare for a 100-hectare project, and only $1.20/hectare for a 10,000 hectare project.

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[20] "A Critical Comparison and Virtual "Field Test" of Forest Management Carbon Offset Protocols," Galik et al., October 2008, op. cit.
[21] This supposition assumes that average break-even prices for all U.S. forest management projects are not significantly lower than those for the Calhoun Experimental Forest in South Carolina discussed here.

Transaction costs under 1605(b) are nearly an order of magnitude lower. CAR's credit and registration fees, project initiation fees, and annual maintenance fees contribute to its relatively high transaction costs, while CCX's per-credit credit registration and trading fees are large drivers of its costs.

The authors believe that high transaction costs and low offset volumes for small projects are likely to lead to the use of aggregators which coordinate projects and sale of offsets to the market, and in some cases provide such services as project validation or verification in exchange for an aggregation fee or a share of total carbon revenues. The authors estimate that transaction costs will increase significantly for small projects in which aggregators charge an aggregation fee in lieu of verification fees. This increase is highest for protocols without stringent verification requirements, for which the aggregation fees becomes an additional cost of doing business.

On the other hand, the study finds that transaction costs are less important than the choice of offset protocol in determining total revenue. The effect of such factors as an aggressive baseline, leakage deductions and buffer set-asides, which strongly impact the volume of creditable offsets from projects, outweigh the effect of transaction costs on project revenue.

Summary

The road testing analyses described here provide clear evidence that quantifying GHG emissions reductions associated with offset projects is a complex undertaking involving many different uncertainties.

The studies reviewed here demonstrate that differences among offset protocols with respect to eligibility, baseline measurement, required and optional carbon pools to be measured (in forestry projects), permanence, leakage and other considerations have significant impacts on the volume of creditable offsets generated by an offset project.

Going forward it will be important for EPA and other federal and state agencies that may be charged with implementing offset requirements and accounting methodologies under any future mandatory federal or regional climate mitigation policies to understand how the selection of different offset protocol requirements can determine whether or not certain offset project categories will be financially viable and how many offsets may be generated by offset projects.

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