Road-testing of Selected Offset Protocols and Standards

A Comparison of Offset Protocols: Landfills, Manure, and Afforestation/Reforestation

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Abstract

Protocols are the foundation of an offset program. By defining eligibility requirements and the quantification of the quantity of offsets generated, protocols will drive the development of emission reduction and sequestration projects. By assuring quality standards for offsets, protocols are also central to the credibility of offset markets. This report examines U.S. EPA Climate Leaders' protocols for landfill methane, manure digesters, and afforestation project types, comparing them with the current versions of protocols developed for four other offset programs: the Clean Development Mechanism (CDM), Regional Greenhouse Gas Initiative (RGGI), California Climate Action Registry (CCAR), and Chicago Climate Exchange (CCX).

We "road test" these protocols for two sample projects for each of three project types to reveal differences in amounts of offsets counted under the different protocols. These differences in offset counts arise from differences in accounting boundary definitions, baseline setting methods, measurement rules, emission factors, and discounts. Overall, the quantitative road test results underscore the importance of standardizing protocols so that at least across offset programs, and for a given project type, "a ton is a ton". Currently, as this road test illustrates, this is not quite the case.

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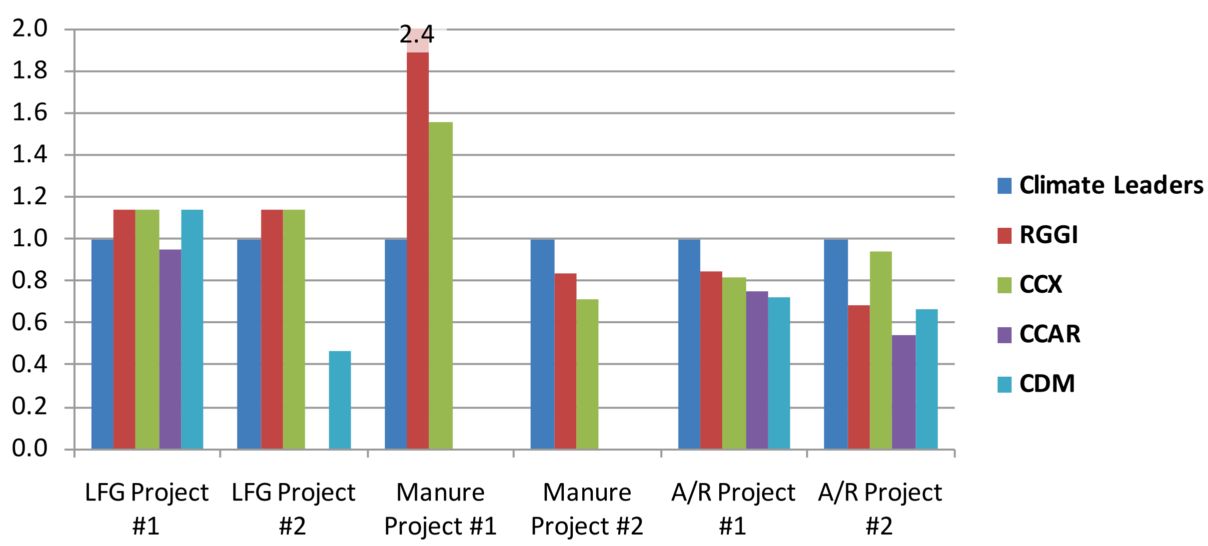
Executive Summary

Protocols[1] are the foundation of an offset program. By defining which activities are eligible to create offsets and how to calculate the quantity of offsets generated, protocols will drive the development of emission reduction and sequestration projects. By assuring that offsets meet adequate quality standards, protocols are also central to the credibility of offset markets.

USEPA's Climate Leaders program has thus far developed a suite of offset protocols across seven categories of offset activities: commercial boilers, industrial boilers, transit bus efficiency, captured methane end use, landfill methane, manure digesters, and afforestation. This report examines Climate Leaders' protocols for the latter three project types, comparing them with the current versions (as of April 2009) of protocols developed for four other offset programs: the Clean Development Mechanism (CDM), Regional Greenhouse Gas Initiative (RGGI), California Climate Action Registry (CCAR), and Chicago Climate Exchange (CCX). We "road test" these protocols for two sample projects for each project type. Such a comparative test helps to reveal where differences arise in project eligibility, offset quantification, and process rigor, and the implications of such differences. These findings can help to increase understanding of the comparability of offsets among programs and project types, and to inform further protocols revisions.

As illustrated in Figure 1 for the sample projects, the amount of offsets credited by various protocols can vary rather dramatically. Overall, the quantitative road test results underscore the importance of improving and standardizing protocols so that at least across offset programs, and for a given project type, "a ton is a ton". Currently, as the road test illustrates, this is not quite the case.

Figure 1. Offsets Credited for Sample Projects, Relative to Estimates using the Climate Leaders Protocol[2] (Climate Leaders value = 1)



We selected or designed sample projects to represent common project characteristics. Nevertheless, one or two sample projects alone will not represent the full spectrum of project circumstances that arise

[1] Offset protocols define the methodology for determining project eligibility and quantifying the emission reductions generated.
[2] In Figure 1, no credits are indicated in cases where sample projects were either ineligible or increased emissions under the protocol applied.

in practice; under some other circumstances, the variation among protocols could differ. The sample projects and specific reasons for differences among protocols are discussed in detail in the body of the report.

Our report reveals a number of other differences among protocols – in additionality, regulatory surplus requirements, monitoring methods, and other elements – that are salient to the further refinement of project protocols. With respect to **general protocol elements**, we find, for instance, that eligible project start dates can be important tools to encourage swift early action and to limit non-additional projects implemented prior to the influence of carbon markets. CCAR's approach of requiring that project proponents begin the process of registration no later than a short time after project initiation (while allowing a grace period for older projects) can help to accomplish both objectives, and should be considered by other programs.

Landfill methane emissions account for almost a quarter of U.S. anthropogenic methane emissions and nearly 2% of total GHG emissions on CO_2e basis. Projects that increase the capture and destruction of landfill gas could represent a significant source of offsets under a future U.S. cap-and-trade program. Landfill methane projects and protocols are often considered among the most straightforward in the offset market. Since baseline emissions are largely a reflection of methane collected, and similar measurement methods are used across projects and protocols, quantification methodologies tend to yield similar results. However, as the comparisons and road test show, there can be a variation of up to 20% in offsets generated across protocols, under simple and common project circumstances. Under more specialized conditions, e.g. the presence of pre-existing LFG combustion equipment, the differences can be stark.

Based on our review and road test of these protocols, we recommend that:

- projects should be eligible to generate offsets up to, but not beyond, the date that a control system is required by regulation. Protocols respond quite differently where changes in regulation or landfill conditions *after initial project verification or registration* trigger legal requirements for the landfill gas control system. Responses range from immediate cessation of eligibility (Climate Leaders) to crediting up to the date the system is required (CCX, CCAR) or until the end of the crediting period (RGGI, CDM). Given that regulation is already widely in place for landfills and it is relatively predictable when a particular landfill will be required to control its emissions, we would recommend adopting the approach used by CCX and CCAR, i.e. project eligibility until the date an LFG control system is required by regulation.
- efforts should be undertaken to develop and adopt common default factors for the efficiency of combustion devices (flares, engines, boilers, etc.). The variation among methodologies can lead to differences in crediting that while small (5-10%) should be readily resolved.
- adoption of CCAR's requirement that project developers submit a public attestation of regulatory additionality. This requirement was added in the most recent version (2.0), as verifiers can otherwise find it difficult to execute their responsibilities.
- the requirement of continuous LFG flow measurement. This is common practice, and significantly reduces error compared with monthly measurement, which the Climate Leaders protocol currently allows.
- adoption of an uncertainty discount for less accurate measurement methods, specifically in the case of less-than-continuous methane concentration measurement.

Manure management represents about 0.2% of total GHG emissions in the U.S. on CO_2e basis, from the emission of methane, and to a lesser extent, nitrous oxide. The use of biogas control systems, such as anaerobic digesters, can reduce methane emissions from livestock facilities where manure is handled under anaerobic conditions in liquids or slurries.

Based on the review of manure methane protocols across various protocols and based on road-testing with sample projects, we recommend:

- adopting CCAR's requirement that project developers submit a public attestation of regulatory additionality, as with landfill methane protocols.
- allowing projects to generate credits for their entire crediting period, even if new emission control rules are enacted during the crediting period, as this would provide an incentive for early action to control emissions. Our recommendation here differs from that for landfill project because the regulation of manure emissions is far less common or predictable.
- additional research to validate the methods commonly used to quantify baseline methane emissions from manure management activities, and, if appropriate, develop alternative methods. Since we did not undertake a scientific analysis, our assessment of sample projects in this report provides no clear indication of the accuracy of the two predominant methods (the use of default annual methane conversion factors (MCFs) and application of the van't Hoff-Arrhenius factor).
- inclusion of the full suite of potentially significant project emissions. For example, only CCAR and CDM protocols include projects emissions from digester effluent, which can be large as in the case of the sample projects considered here. CCX and RGGI assume 100% collection and destruction efficiency of biogas, which could overstate emission reductions. Climate Leaders include nitrous oxide but not methane emissions from non-digester manure management.
- further assessment of baseline (and project) nitrous oxide emissions from field spreading of manure (and digester effluent), which could be quite significant but is subject to considerable uncertainty. In some project circumstances, e.g. where field spreading is the baseline management method, nitrous oxide from field spreading can be the single largest source of baseline emissions. Counting this source can mean the difference between generating offset credits and not doing so (see analysis of sample project #1 in Section 4 below).
- inclusion of provisions that baseline CH_4 emissions cannot exceed the quantity of CH_4 captured and destroyed by the project digester. Digesters, which are typically engineered and operated to maximize methane production, will tend to produce more methane than pre-project management systems, such as lagoons. Currently, RGGI, CCAR, and CDM all include such a provision, which guards against over-crediting.
- further specification of monitoring requirements. In order to verify that CH_4 captured by the digester is being destroyed and flared as CO_2, protocols could consistently include monitoring requirements, similar to those of CCAR, for the operation of the manure digester/flare and inspection of biogas instruments..

Afforestation and reforestation, along with forest management, are widely considered to be the largest sources of domestic offsets under a potential cap-and-trade system in the U.S.[3] Therefore, the feasibility, rigor, and accuracy of forestry protocols could prove critical to the both the environmental integrity and cost of U.S. climate policy.

Based on our review of protocols for afforestation and reforestation, we recommend:

- further research on how to address leakage for afforestation projects. Leakage can make a large difference in the actual atmospheric benefit resulting from a project. There is uncertainty about the actual extent of leakage from afforestation projects, and leakage is significantly affected by the overall global economy. There are significant concerns either with assuming zero leakage for afforestation projects or with the substantial leakage rates calculated by methods such as the RAPCOE tool described in Section 5.
- further specification of methods for monitoring and measuring carbon stocks. To maximize the accuracy of carbon stock measurement, we recommend the use of allometric equations based on tree species, height and diameter.
- conditional inclusion of particular pools and fluxes, based on tests to determine the significance of carbon pools and fluxes (other than live trees). Several carbon pools and fluxes are frequently trivial in afforestation projects, such forest floor, shrub, and soil.
- exclusion of wood product carbon from afforestation project offset accounting.[4] Wood product harvest is a business-as-usual activity; unless the project is increasing the demand for wood products or supplying otherwise unmet demand, then there is no net increase in carbon in wood products due to the project. Furthermore, because wood products are generally not owned or controlled by the landowner, there is a risk of double counting if wood products are counted both at production and at internment at landfill sites.
- exclusion of methane emissions in afforestation project accounting. If methane emissions from burning are included, we recommend that field sampling be conducted to develop new factors for estimating methane emissions from burning.
- improved provisions for addressing the risks of reversals of sequestered carbon. Permanence of forest emission offsets is a very important issue. For voluntary offset programs where limited enforcement of old offset agreements can be expected, requiring permanent conservation easements or granting of land to conservation agencies is the most effective method of providing permanent atmospheric benefit. For compliance programs, serial numbers of affected offsets can be cancelled if a project developer ceases to provide periodic verification that sequestration continues. Although project developers can be held liable for replacing reversed offsets, these claims are likely not to be very enforceable unless the claims are recorded with the land deed. Alternatively, offsets can be considered permanent if the land is conveyed to a conservation agency and a fraction of achieved sequestration is withheld to cover reversals. If forest offsets are to be used for compliance, we recommend that either (a) periodic assessment of continued carbon storage be required and landowners be liable for replacing reversed offsets,

[3] EPA Analysis of the Lieberman-Warner Climate Security Act of 2008, http://www.epa.gov/climatechange/downloads/s2191_EPA_Analysis.pdf.

[4] While we recommend exclusion of wood product carbon from afforestation project accounting, it may nonetheless be appropriate to consider for forest management or avoided deforestation projects.

or (b) land be owned by a conservation entity and a fraction of the sequestered carbon be held in reserved to cover emissions from disturbances such as fire.

Overall, we find that, while considerable progress has been made over the past decade in advancing offset project protocols, more work is needed to improve and, if appropriate, standardize them if they are to serve as the basis for rigorous, large-scale offset markets.

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1 Introduction

1.1 Context

Protocols[5] are the foundation of an offset program. By defining which activities are eligible to generate offsets and the quantity of offsets they can generate, protocols will drive the development of emission reduction and sequestration projects. By assuring that offsets meet adequate quality standards, protocols also become central to the credibility of offset markets.

USEPA's Climate Leaders program has thus far developed a suite of offset protocols across seven categories of offset activities: commercial boilers, industrial boilers, transit bus efficiency, captured methane end use, landfill methane, manure digesters, and afforestation. This report examines Climate Leaders' protocols for the latter three project types, comparing them with protocols developed for four other offset programs: the Clean Development Mechanism (CDM), Regional Greenhouse Gas Initiative (RGGI), California Climate Action Registry (CCAR), and Chicago Climate Exchange (CCX).

More specifically, we "road test" these protocols, by taking sample landfill, manure digester, and afforestation projects for a spin. Such a comparative test helps to reveal where differences arise in project eligibility, offset quantification, and process rigor, and the implications of such differences. These findings can help to increase understanding of the comparability of offsets among programs and project types, and to inform further protocols revisions.

This analysis builds upon a prior EPA road test exercise that compared [different] sample projects to a somewhat different group of alternative protocols (Climate Leaders, ERT, CCX, and 1605b). We refer to the findings of this prior analysis throughout this report as "ERT Road-test".

Issues addressed include, among others:

- Project Type: Does the protocol state the applicable project location, technology, and size? If so, how does the defined project type differ from that defined by Climate Leaders?
- Project Boundary: What is included in the physical, GHG, and temporal boundaries under the protocol? How does it differ from CL? Does the protocol require that the project account for leakage? If so, from which sources? How is it to be accounted?
- Regulatory Eligibility: Does the protocol include regulatory eligibility screens that require projects to be surplus to federal, state and local actions? How does the protocol treat legal agreements, or federal and state programs that compensate voluntary action?
- Performance Thresholds and Emissions Baselines: How does the protocol determine additionality? Is the project additional under this protocol? What is the emission baseline for calculation?
- Project GHG Emissions Reductions: What is the quantity of emissions reductions calculated by using the protocol? Provide summary information of reasons for any differences in calculated post-project emission reductions under different protocols.
- Project Monitoring: What guidance is available on monitoring? How does it compare to that offered by Climate Leaders?

[5] Offset protocols define the methodology for determining project eligibility and quantifying the emission reductions generated.

- Project Emission Reductions: Does the protocol provide a software tool, model or equations for pre-project estimation? How do the results differ from those developed using the Climate Leaders Protocol?

Key documents reviewed include offset program general guidance documents and protocol methodologies for each project type evaluated (landfill methane, manure methane, and afforestation/reforestation).

1.2 Offset Programs Considered Here

The offset programs selected for this comparison with Climate Leaders were chosen to give a view of the range of protocols used in voluntary and compliance offsets markets. Both the CDM and RGGI offset programs are specifically designed to serve as compliance mechanisms under the respective international and regional regulations. CCAR and Climate Leaders programs are voluntary GHG reduction programs. CCX serves as a voluntary program for emission reductions through cap and trade system among CCX members. CCX does not have a regulatory affiliation, but emissions reductions targets are legally binding. General features of the offset programs evaluated in this report are included in Table 1.

Offset projects protocols are generally in state of periodic revision; some of those reviewed have gone through over a dozen versions. Therefore, the analysis presented here represents a snapshot in time, reflective of the protocols in play in spring 2009.

Table 1. General Features of Offset Programs

Program	Regional scope	Type of Program	Start of Program	Program Administrator
Climate Leaders	Primarily U.S.	Voluntary compliance program with offsets as unlimited compliance mechanism.	Launched in 2002.	The U.S. Environmental Protection Agency (EPA)
Clean Development Mechanism (CDM)	International (covers all countries that have ratified the Kyoto Protocol)	Project-based offset mechanism under the Kyoto Protocol	General rules established in 2001, first offset issued in 2005	CDM Executive Board
Regional Greenhouse Gas Initiative (RGGI)	Northeast U.S. states: CT, DE, ME, NH, NJ, NY, VT, MA, RI, and MD	Mandatory regional cap and trade with offsets as limited compliance mechanism	Started in 2009.	State regulatory agencies
California Climate Action Registry (CCAR)	U.S. (mainly California)	Voluntary GHG reduction program and registry	Active since 2002	Board of Directors, CCAR Registry Staff
Chicago Climate Exchange (CCX)	Originally only in the U.S. but has been expanded. International membership now possible.	Voluntary compliance cap and trade with offsets as unlimited compliance mechanism	Launched in 2002	CCX Committee on Offsets.

1.3 Role of Sample Projects in the Road Test

In this report, sample projects are used to “road test” protocols. The sample projects illustrate some of the practical differences among protocols as they apply to actual project circumstances. We selected or designed sample projects to represent common project characteristics. Nevertheless, one or two sample projects alone will not represent the full spectrum of project circumstances that arise in practice. This is especially true for manure management projects where a variety of project parameters such as animal type and baseline management practices can have quite different impacts depending on the protocol. As a result, the reader should be mindful that the sample projects reveal only some of the many differences among protocols.

Quantification of emission reductions from sample projects can serve to provide a general sense of how quantification approaches differ across protocols. We note where a sample project would likely be ineligible under a protocol – for instance, U.S. projects would be ineligible under the CDM and some sample projects predate eligible start dates for some programs -- we nonetheless quantify emissions reductions for the purposes of comparison.

1.4 Roadmap of the Report

In Section 2, we compare many of protocol elements that are common across project types, such as crediting periods, eligible locations, and start dates. In Sections 3, 4, and 5, we examine protocols for landfill methane projects, manure methane projects, and afforestation/reforestation, respectively. Each of these sections includes two components: 1) a general comparison across project protocol parameters and 2) an evaluation of the implications for sample projects under each offset program protocol.

2 Common Protocol Features

Several protocol features are common to all project types including additionality approach, regulatory surplus requirements, baseline determination, process requirements, and offset project eligibility requirements. Major differences in these common protocol features are presented in this section.

2.1 Additionality and Regulatory Surplus

All programs require a regulatory surplus test. In order for a project of any type to be eligible under any one of these offset programs it must demonstrate that the project activity is not already required by regulation. There are nonetheless some differences in approach to regulatory surplus, such as the scope of laws and rules considered, as discussed on a project-type-specific basis below.

General additionality approaches, as presented in Table 2, do differ across programs. Project-type standards provide "standardized" methods to determine additionality under the Climate Leaders, RGGI, and CCAR programs. These standards can either be performance-based, with a threshold defined in terms of emissions per unit output or other metric, or practice-based, where in a given practice is determined by the program authority to be beyond business-as-usual. CCX has no formal definition of additionality; project eligibility criteria provide a primarily performance-based where project eligibility requirements serve to establish which projects are deemed additional. Implicitly, as with RGGI for some project types, the program authority is using a practice-based standard that deems such practices automatically additional. By virtue of their highly standardized additionality methods, these programs provide project developer with substantial certainty as to whether their project will be considered additional. Standardized approaches do nonetheless explicitly allow a certain amount of non-additional projects and tons; under these programs, a qualifying project may be considered additional even if the presence of a carbon market incentive had no bearing whatsoever on project implementation.

CDM is the only program reviewed here that focuses primarily on project-by-project additionality assessment. The CDM additionality tool requires a common practice test, where the extent of diffusion of the proposed project activity is assessed, and either an investment or barrier analysis test to fully demonstrate additionality. While seeking to elicit whether the carbon market incentive was instrumental in a project's fruition, the CDM additionality tool creates some uncertainty for project developers, and has been criticized for allowing a significant amount of non-additional activity.

The choice of additionality methodologies should be viewed in light of the offset program context. With some exceptions, the U.S. based offset programs have issued protocols for project types for which there is limited business-as-usual activity. With CDM, on the other hand, the majority of projects, and a substantial fraction of credits, are associated with project types for which there is considerable BAU activity – energy efficiency, renewable energy, and fuel switching – and straightforward practice-based or performance-based standards are particularly difficult to establish.

Table 2. Additionality Approach

Program	Project-type standards		Project-specific analysis		Other
	Performance standard?	Practice-based standard?	Common Practice Test?	Investment or Barrier Test?	
Climate Leaders	X	X			
CDM		X	X	X	
RGGI	X	Implicit			No funding from system or customer benefit fund No credits or allowances awarded under any other mandatory or voluntary GHG program.
CCAR	X	X			
CCX		Implicit			All new projects in eligible categories are deemed additional

2.2 Process Requirements

Each offset program has an established set of process requirements, which are outlined in Table 3. Climate Leaders' process requirements differ from the other programs in two ways. First, Climate Leaders is the only program that uses government rather than independent third party verification of project data. Under the Climate Leaders program, the EPA staff serves to both validate/verify, as well as approve/register projects.

Second, the use of a registry to track emission reductions is required under all of the programs, except for Climate Leaders, which recommends but does not require it. Without the use of a registry, the ownership and status of emission reductions generated under the Climate Leaders would not be tracked.

Table 3. Process Requirements. Verification, validation, certification, registration, timing of crediting and crediting period requirements by program.

Program	Who validates/ verifies?	Who approves/ registers?	Name of Registry	Timing of Crediting	Crediting Period
Climate Leaders	EPA	EPA	Use of registry recommended, not required.	Ex-post	Based on goal period of Climate Leaders Partner company.
CDM	Designated Operational Entities (DOEs)	CDM Executive Board	CDM Registry	Ex-post	Either one 10 yr period or 7 yr with up to two renewals. For afforestation/reforestation projects, either one 30 yr period; or 20 yr with up to two renewals
RGGI	Accredited independent verifier	State regulatory agencies	Under development	Ex-post	Initial 10-yr period followed by 10-yr renewal with approval Afforestation: 20-yr period with renewal
CCAR	Approved third-party verifiers	State of California and CCAR	The California Registry	Ex-post	Manure management: 10-yr period Landfill projects, shorter: 10-yr period or up until regulation Forestry: 100 yr period
CCX	CCX-approved verifiers	CCX Comm. on Offsets	CCX Registry	Ex-post	8-yr. period

2.3 Offset Project Eligibility Requirements

Eligible project locations and start date differences across offset programs are presented in Table 4. CCAR and Climate Leaders only permit projects within the U.S. (with some exceptions), RGGI only within the 10 RGGI participating states or other approved jurisdictions with specifications to expand project location restrictions if emission allowances exceed a series of price triggers, and although CCX projects are heavily U.S. dominated, they can be located internationally. CDM projects must be located in developing (non-Annex 1) countries.

Project start dates tend to be set at or near the date that the respective program was announced and range from 1999 to 2005. Start dates can vary by project type, as is the case under CCAR and CCX. Starting dates are generally set in a manner to balance the desire to reward early actors (with early start dates) and the goal of minimizing non-additional projects. In the case of projects with start dates prior to the establishment of offset protocols, the influence of carbon markets on their viability can often be questioned. To address these concerns, the most recent CCAR landfill protocol has adopted a hybrid approach to start date eligibility. Projects that became operational prior to the effective date of the protocol (November 2008) are eligible only if they list with the Reserve within 12 months of that date.

Table 4. Offset Project Eligibility Requirements. General offset eligibility requirements including project start date and project location are included for the offset programs considered.

Program	Eligible Project Locations	Project Start Date
Climate Leaders	U.S. Project developers able to develop a performance standard for an international project type can propose an international project.	February 20, 2002
CDM	Developing (non-Annex 1) countries where Designated National Authorities (DNAs) are established	January 1, 2000
RGGI	Within RGGI participating states or other approved jurisdictions If allowances exceed trigger price (USD 10), offsets allowed from any governmental mandatory program outside U.S. with a limit on GHG emissions.	December 20, 2005
CCAR	U.S.	Carbon sequestration: January 1, 1990 Methane capture[6]: January 1, 2001 or six months from operation
CCX	Any country except Annex 1 countries that are Party to the Kyoto Protocol	January 1, 1999 except Forestry projects: January 1, 1990

2.4 Conclusions

With respect to general protocol elements,

- Differences in project locations influence protocol design. CDM's focus on developing countries renders its ability to standardize more challenging, since it covers over 100 eligible countries in four continents with widely varying common practices and levels of performance. CDM protocols must also address wide variations in data availability, data quality, and local capacity to measure and monitor.
- Eligible project start dates can be important tools to encourage swift early action and to limit non-additional projects implemented prior to the influence of carbon markets. CCAR's approach of allowing the registration of early action projects only until a clearly stated date can help to accomplish both objectives, and should be considered.

[6] Defined as the date the destruction device becomes operational.

3 Landfill Methane

The anaerobic decomposition of waste in landfills represents almost a quarter of anthropogenic methane emissions in the U.S., and nearly 2% of total GHG emissions on CO2e basis.[7] While larger landfills are generally required by federal regulation to install and operate methane capture and combustion equipment, a larger number of smaller landfills are not subject to regulatory requirements. Currently, approximately 80% of landfills not subject to federal legislation do not have gas collection and combustion systems in place (Climate Leaders, 2008). In addition, with additional investments, many landfills with existing gas collection and combustion systems can increase methane capture and destruction.

Landfill gas projects represent a major opportunity for emission reductions, offset creation, and multiple co-benefits including renewable energy production, employment generation, and odor control. EPA estimates 540 candidate landfills could generate 240 billion cubic feet per year in natural gas (sufficient to heat 1.5 million homes) or 1.3 GW of electricity (800,000 homes).[8]

Offsets from landfill methane projects represent a significant component of the U.S. voluntary market today, comprising approximately 10% total traded volume in one recent survey.[9] The EPA projects that offsets from landfills might deliver 15-20% of total offsets under some designs of a U.S. cap and trade system.[10]

In this section, we contrast five protocols for landfill methane projects, and apply them to the circumstances found in two sample projects. Differences in crediting among protocols will depend on a host of project parameters, ranging from how pre-project conditions are considered to the project technologies used. The sample projects can reflect only some of these differences. Therefore, in the subsections that follow on eligibility, regulatory surplus and other protocol elements, we discuss general protocol differences before we show how they address the particular circumstances of the sample projects.

3.1 Descriptions of sample projects

We combined characteristics of several offset projects in the current voluntary market to develop two sample projects that are either illustrative of typical project conditions or key differences in protocols.

LFG Project #1: A small municipality contracted with a project developer in 2003 to establish a Landfill Gas-to-Energy (LFGTE) project at a landfill that has been in operation since the 1980s. By 2005, three engine-generator sets (totaling 5 MW) were installed and fully operational, producing a total of electricity with near 95% availability. The project developer now owns and operates the landfill's electricity generation on behalf of the municipality. A utility has an agreement to purchase the electricity as well as associated renewable energy credits (RECs), and a carbon broker has agreed to purchase and resell the verified carbon offsets associated with methane emission reductions. The project has been validated by a 3rd party and approved by an offset registry. Project documentation also states that the landfill gas collection and destruction system was installed specifically to address potential odors and reduce landfill surface emissions.

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[7] EPA, 2009. Draft Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2007, http://epa.gov/climatechange/emissions/usinventoryreport.html

[8] http://www.epa.gov/lmop/docs/overview.pdf

[9] Appendix 2, State of the Voluntary Carbon Market, http://www.ecosystemmarketplace.com/documents/cms_documents/2008_StateofVoluntaryCarbonMarket2.pdf

[10] EPA Analysis of the Lieberman-Warner Climate Security Act of 2008, http://www.epa.gov/climatechange/downloads/s2191_EPA_Analysis.pdf

Since the landfill's design capacity is larger than 2.5 million Mg of municipal solid waste, it is subject to NSPS rules. It must install a gas collection and control system within 30 months after the first annual NMOC emissions rate report in which the emissions rate equals or exceeds 50 Mg/yr. Testing in recent years showed NMOC emissions to be below this level.

LFG Project #2: This project context is nearly identical to that found in project #1. In this case, however, the landfill had a pre-existing collection and destruction system, which captured and destroyed a smaller fraction of methane generated than the expanded collection and LFTGE system installed by the project. For clarity of comparison, the post-project conditions are the same as for Project #1.

3.2 Protocols considered

All of the offset programs described in Section 2 have issued landfill methane protocols. Many of these protocols have undergone several iterations, often with quite substantive changes. For example, the most recent CCAR protocol (Version 2.0) tightens requirements for project start dates and regulatory additionality, broadens eligibility (to landfills with pre-existing, non-qualifying destruction devices and to the use of open flares as a qualifying destruction device), and modifies methane destruction calculations.[11] The specific protocol names and versions each offset program evaluated in this section are listed in Table 5, along with the number of projects listed.[12]

Table 5. Landfill Methane Protocol Methodologies and Projects Registered

	Climate Leaders	RGGI	CCX	CCAR	CDM
Protocol Version Reviewed	Version 1.3, August 2008	RGGI Model Rule (2007)	Chapter 9 (2004)	Version 2.0 November 2008	ACM0001 (version 10)
Number of Landfill Projects Listed (March 2009)	None	None	>30 registered [13]	1 registered 14 listed[14]	97 registered 101 at validation or reg. request[15]

3.3 Additionality, Regulatory Surplus and Other Eligibility Requirements

The protocols examined here are applicable to most landfill capture and combustion technologies and project conditions. However, as noted in Table 6 (bottom row), CCX and CCAR exclude specific landfill management technologies such as geomembranes, bio-covers, and bioreactors. The CDM landfill protocol (ACM0001) is also applicable to the end use of landfill gas, while under Climate Leaders, a separate methane end use project protocol must be used. None of the other programs considered will

[11] See Updates to the Landfill Project Protocols for an explanation of the changes. http://www.climateregistry.org/resources/docs/protocols/project/landfill/revision/summary-of-changes-landfill-project-protocol-v2.0.pdf

[12] Climate Leaders has developed a separate protocol for end use of captured methane projects, which can include landfill, as well as, manure methane among sources.

[13] http://www.chicagoclimatex.com/offsets/projectReport.jsf as accessed on March 26, 2009.

[14] https://thereserve1.apx.com/myModule/rpt/myrpt.asp as accessed on March 26, 2009.

[15] As of March 1, 2009. http://www.cdmpipeline.org/cdm-projects-type.htm. Includes LFG flaring and energy only.

provide offset credit the emission benefits of the use of landfill gas to substitute for higher GHG fuels or electricity.

Under the four U.S.-based protocols, all new landfill gas collection and destruction systems not required by regulation and at sites without a pre-existing destruction system are considered additional. Both Climate Leaders and CCAR use a somewhat different performance standard approach to arrive at the same conclusion; both are based on the observation that only slightly over 20% of unregulated landfills currently combust landfill gas.[16] RGGI adds the additionality stipulation that projects are not eligible if support from funds or incentives are provided; this could result in excluding LFTGE projects that are collect renewable energy tax credits or generate renewable energy credits. CDM is the only protocol that utilizes a project-specific additionality test.

As outlined in Table 6, landfills subject to regulation, permitting requirements, ordinances or rulings requiring the installation of a landfill gas collection and destruction system at the project location are generally ineligible under the protocols considered here. That said:

- Protocols differ in terms of specificity of requirements. Climate Leaders refers to a variety of federal, state, and local regulations that might affect eligibility, and CCX refers only to national regulations. It is unclear whether a project subject to state or local requirements would nonetheless be eligible under CCX.
- CCX appears to be the only protocol that explicitly allows for the registration of offset projects that are subject to regulatory requirements to control landfill gas *at the time of initial verification or registration* but for which the landfill gas control system is legally required to be operational at a later date. (“Early installation”)
- Protocols respond quite differently where changes in regulation or landfill conditions *after initial project verification or registration* trigger legal requirements for the landfill gas control system. Responses range from immediate cessation of eligibility (Climate Leaders) to crediting up to the date the system is required (CCX, CCAR) or the end of the crediting period (RGGI, CDM).
- Monitoring of changes in regulation is required for Climate Leaders, RGGI, CCAR, and CDM; for the latter two, such monitoring is annual, for the former two, frequency is not specified.
- CCAR is the only protocol that requires project developers to submit a public attestation of regulatory additionality. This requirement was added in the most recent version (2.0), as verifiers can otherwise find it difficult to execute their responsibilities, as regulatory review can be a significant burden.

Projects that expand upon (pre-project) limited (minimal) LFG control systems are treated quite differently depending on the protocol. Several LFG offset projects take place where a less extensive or less efficient system is already in place. CCAR, CDM, and Climate Leaders all consider such projects as eligible for “beyond baseline” methane destruction. Both CCAR and CDM contain explicit baseline methodologies to estimate and deduct emissions that would have otherwise been destroyed by pre-existing systems, while Climate Leaders does not provide a baseline methodology, but instead requires that these projects be physically separate, and monitored separately from the existing system.[17] Nothing

[16] CCAR also notes that, excluding flare only sites, only 9.5% of unregulated landfills currently combust landfill gas, which they argue, serves a lower bound of business-as-usual implementation. Neither CCAR nor Climate Leaders provide a clear criterion for setting performance based standards (e.g. market penetration less than X %).

[17] Cases where collection systems are in place to address local nuisance laws or to prevent lateral migration of the landfill gas to neighboring properties but that are not required to control NMOCs are eligible as GHG offset

in the CCX and RGGI protocols would appear to render such projects ineligible. In general, it is quite difficult to ascertain the precise intent and implications of protocol language with respect to pre-existing systems.

The CCAR protocol provides added eligibility criteria in the case where a landfill is required to treat landfill gas for NMOC in order to comply with a regulation, ordinance or permitting condition, but destruction of the landfill gas is not the only compliance mechanism available to the landfill operator.[18]

projects for those reductions resulting from collection and combustion of landfill gas beyond that from the system currently in place.

[18] In cases where landfill gas treatment required, but combustion is not the only compliance mechanism, a non-methane organic compounds (NMOC) emissions threshold has been developed to determine eligibility – total mass flow of NMOC for gas control system must be less than 600 lbs. per month.

Table 6. Additionality, Regulatory Surplus and Other Eligibility Requirements of Landfill Protocols

Protocol Parameter	Climate Leaders	RGGI	CCX	CCAR	CDM
Additionality Methodology	Practice-based performance threshold	Projects are not eligible if support from funds or incentives are provided.	General CCX guidelines apply	Performance Standard Test	CDM additionality tool
Regulatory Surplus Requirements	Activities required by federal (NSPS[19], EG, the NESHAP[20]), state or local regulations are *ineligible*. Monitoring of regulatory requirement changes[21]	Activities required by any local, state or federal law, regulation, or administrative or judicial order are *ineligible*	Activities *eligible* during time periods where gas control systems not required by U.S. federal regulations.	Activities required by federal, state or local regulation, or in non-compliance with other air or water quality regulations, are *ineligible*. Public attestation of regulatory compliance by project developers required.	CDM additionality tool
Allows projects that are early installations of control systems required by regulation?	No	Not specified	Yes	No	No (not considered additional)
If gas control system is required by regulation after initial approval	Ineligible once landfill meets or exceeds NMOC limit under NSPS or EG	Project remains eligible through the current crediting period, but cannot be extended.	Eligible until date that the landfill gas control system is legally required to be operational.		Adjust baseline at the start of next crediting period.
Frequency of regulatory analysis in M&V	Not specified	Not determined	Not determined	Annual	Annual
Landfills with minimal/pre-existing gas collection systems in place.	Eligible. Must be physically and monitored separate from the project system		Expanded recovery from regulated sites not eligible.	Eligible for LFG destroyed beyond the *maximum capacity* of the pre-project destruction device, new project requires separate destruction device.	*Eligible* for LFG beyond fraction required to be captured and destroyed by regulation or contract
Excluded technologies			Geomembranes, bio-cover, bioreactors ineligible.	Bioreactors ineligible.	

[19] New Source Performance Standard: 40 CFR 60 subpart WWW. Emission Guidelines for Municipal Solid Waste Landfills: 40 CFR 60 subpart Cc. Landfills with a design capacity of at least 2.5 million megagrams and 2.5 million cubic meters of municipal solid waste are subject to the NSPS or EG rules. Landfills above the design capacity size cutoff must calculate their annual NMOC emissions using equations or procedures in the NSPS or EG rules. The landfill must install a gas collection and control system within 30 months after the first annual NMOC emissions rate report in which the emissions rate equals or exceeds 50 Mg/yr.

[20] National Emission Standards for Hazardous Air Pollutants: 40 CFR 63 subpart AAAA

[21] Specified as monitoring requirement, not included as a regulatory surplus requirement.

3.3.1 Implications for Sample Projects

Project #1: This project is generally eligible and additional under the protocols reviewed here. Under the four U.S.-based protocols, all new landfill gas collection and destruction systems not required by regulation and at sites without a pre-existing destruction system are considered additional. The exception could be CDM. As noted above, this project was implemented for the purpose of odor control and reducing landfill surface emissions. Carbon offsets were not considered at the time of project development. The project proponents could pass the CDM additionality test, though a validator or the CDM Executive Board might question whether the offset credits played any role in overcoming barriers to implementation, and thus reject it.

Project #2: The project *appears likely* to be eligible and additional under all protocols here, but for the project-specific additionality concerns in CDM noted for Project #1. However, with RGGI and CCX, there are no specific provisions for pre-existing LFG control systems.

3.4 Project Boundary and Leakage

The exclusion/inclusion of sources/sinks in the landfill methane project activity and baseline determination for each protocol is outlined in **Table 9.** Project and baseline activity boundaries vary in several ways across the protocols compared:

- All protocols consider project related emissions from gas collection and combustion system for methane gas.
- Only CDM, Climate Leaders, and CCAR also consider (CO2) emissions from fossil fuel use at project facilities.
- Climate Leaders differs from other protocols by including consideration of N2O emissions consistently in all project related sources.
- Soil oxidation of methane is considered for estimating baseline emissions only in the Climate Leaders, RGGI and CCAR protocols.
- Unlike the other landfill protocols, the CDM landfill also includes project and baseline emissions related to the end use of landfill methane.[22]
- Project-related construction emissions are considered only under the Climate Leaders protocol.

[22] Climate Leaders addresses the end use of methane in a separate protocol for Captured Methane End Use.

Table 7. Project and Baseline Activity Boundary for Landfill Methane Protocols. Emissions sources included or excluded from the project and baseline activity boundary are included in the table below by protocol.

	Physical Boundary and Emissions Sources or Sinks Included	Gas	Climate Leaders	RGGI	CCX	CCAR	CDM
Baseline Activity	**Landfill gas generation**	**CH4**	Y	Y	Y	Y	Y
	Soil oxidation	**CH4**	Y	Y	N	Y	N
Project Activity	Gas collection and combustion system	Fossil fuel CO2	Y[23]	N	N	Y[24, 25]	Y[26]
		CH4	Y	Y	Y	Y[27]	Y
		Fossil fuel **N20**	Y	N	N	N	N
	Project related construction	Fossil fuel **CO2**	Y	N	N	N	N
		CH4	Y	N	N	N	N
		Fossil fuel **N20**	Y	N	N	N	N

Provisions for accounting for leakage under each protocol are outlined in Table 8. RGGI, CCX, and CDM do not require consideration of leakage. No specific methodologies for evaluating leakage are proposed by any of the protocols. Both CCAR and Climate Leaders acknowledge leakage concerns, though CCAR assumes it not to occur for these project types and Climate Leaders only requires quantification if emissions from leakage are believed to be significant. We are unaware of any landfill projects for which leakage has been estimated or has otherwise affected emission reduction calculations.

Table 8. Leakage Provisions for Landfill Methane Protocols

Protocol Parameter	Climate Leaders	RGGI	CCX	CCAR	CDM
Leakage	Considered on case-by-case basis	Not considered	Not considered	Limited to activity shifting – for this protocol assumed to not occur	No consideration required.

Implications of different boundary definitions are best illustrated in the quantification subsection that follows.

[23] Climate Leaders protocol includes emissions from gas collection, piping, blowers, flare. This includes emissions of CO_2 from any fossil fuel used to assist the flare, etc. It does not include CO_2 from the combustion of landfill methane.
[24] CDM protocol includes emissions from wells, pipes, blowers, caps, and other technologies for collection and combustion
[25] Includes indirect and direct emissions from fossil fuel combustion for compressors, blowers and gathering systems
[26] For partial existing capture projects, fossil fuel of baseline should be accounted for.
[27] Un-combusted CH4 from natural gas sent to destruction device.

3.5 Quantification of Baseline and Project Emissions

The overall approach to quantifying baseline and project emissions is common across all landfill protocols. With minor adjustment, they all calculate:

> Baseline emissions = landfill gas collected x methane concentration x combustion efficiency x (1-soil oxidation factor) x measurement uncertainty discount (CCAR only)

Some protocols also explicitly include project emissions (CCAR, Climate Leaders, CDM), largely associated with natural gas used for more complete combustion or as a backup fuel for on-site end use equipment. However, in most circumstances, project emissions will be zero or quite small. As a result, in most cases, emission reductions will equal baseline emissions. Since baseline emissions are largely a reflection of methane collected, and similar measurement methods are used across projects and protocols, quantification methodologies tend to yield similar results for landfill projects, particularly compared with the divergences found with the other project types discussed in this report.

Protocols do however, differ in terms of:

- Combustion efficiencies. As shown in Table 9 below, there is considerable variation in assumed methane destruction efficiencies across protocols and technologies. The differences are greatest for open flares (50% efficiency in CDM vs. 100% in CCX). With respect to this factor, CCX and Climate Leaders are the least conservative protocols, with 100% and 99% efficiencies assumed for all technologies. CCAR is the only protocol that distinguishes efficiencies among end-use devices; their factors are based on actual source test data.

Table 9. Comparison of Default Values

	Climate Leaders	RGGI	CCX	CCAR	CDM
Methane GWP	21	23	21	21	21
Soil Oxidation Factor	10%	10%	0%	10% (0% if synthetic cover used)	0%
Electricity Emission Factor (for Project Use)	Regional EGRID average emissions	n/a	n/a	n/a	ACM0002 (combined margin)
Methane Combustion Efficiency					
Open Flare	99%	98%	100%	96.0%[28]	50%
Closed Flare	99%	98%	100%	99.5%	90% or monitored
Lean-Burn Engine	99%	98%	100%	93.6%	100%
Turbines, Rich-Burn Eng.	99%	98%	100%	99.5%	100%
Boiler, pipeline gas	99%	98%	100%	98.0%	100%
Vehicle Use (LNG/CNG)	99%	98%	100%	95.0%	100%

- Methane GWP. RGGI departs from common practice of using IPCC SAR GWPs, using the more recent value of 23, effectively increasing crediting by 10% relative to other protocols.
- Methane densities. Protocols differ in how they specify density. After correcting for differences in how STP (standard temperature and pressure) are defined, we still find a difference of over 3% in density values. Since this a factor with little uncertainty, this difference should be rectified.

[28] Official or accredited source tests for specific combustion devices may be used instead of the defaults.

- Treatment of soil oxidation processes. As noted above, this is considered only under the Climate Leaders, RGGI, and CCAR protocols.
- Baseline adjustments for pre-existing control systems, as illustrated in Table 10. This is probably the most significant difference, though it affects only a fraction of all projects.
  - Specific equations are provided in CCAR and CDM protocols. The CCAR protocol assumes that under the baseline, the pre-existing system would have combusted collected methane up to the maximum capacity of the pre-existing equipment. The CDM methodology, in contrast, assumes that the pre-existing system would have combust methane only up to historical combustion levels. Unlike the CCAR approach, the CDM methodology implicitly assumes that the project system accounts for the increase in methane collection. As we will see in the case of sample Project #2, this can yield a large difference in outcome.
  - No method for deduction of baseline methane destruction from pre-existing conditions is specified in CCX, or RGGI. In the case of Climate Leaders, pre-existing collection and combustion systems must be physically separate from the project or "monitored separately"; unlike CCAR and CDM protocols, however, the method for doing so is not stated. As noted above, the intent of the CCX and RGGI protocols is unclear in such circumstances; our reading of these protocols however would be to credit all methane combusted by the project, and thus to disregard the pre-existing system. Therefore, these two protocols appear capable of significantly over-crediting some landfill projects relative to business-as-usual.

Table 10. How Protocols address pre-existing collection and destruction systems

Climate Leaders	RGGI	CCX	CCAR	CDM
Must be physically separate or monitored separately	Not specified	Unclear (Includes method for expansion into new refuse cells installed after 1999)	Deducts portion of gas that could have been destroyed by the pre-existing device, based on its *maximum capacity*	Applies adjustment factor that reflects fraction of gas that would have been captured/destroyed based on historical data

3.5.1 Implications for Sample Projects

Figure 2 illustrates the overall variation in offset counts (for a given year) for the two sample projects. As shown, for project #1, which represents a typical project situation with no prior LFG control system, the results are relatively similar. RGGI, CCX, and CDM protocols yield results that are within 1% of each other. In the case of RGGI, two countervailing factors, a higher GWP and the soil oxidation discount, roughly cancel, as shown in Table 11. CCAR and Climate Leaders, however, are both affected by the 10% soil oxidation factor, as well as additional deductions for project emissions due to fossil fuel use and non-combusted methane. As a result, the Climate Leaders and CCAR protocol, for this project situation, credit 15-20% fewer emission reductions than RGGI, CCX, or CDM. This difference would be somewhat less were the project using a different combustion technology with more complete combustion (flares, boilers). In the case that flares were in use, however, CDM would attribute 10% (closed, unmonitored) to 50% (open) fewer emission reductions than shown.

Figure 2. Estimated offsets for sample projects under various protocols

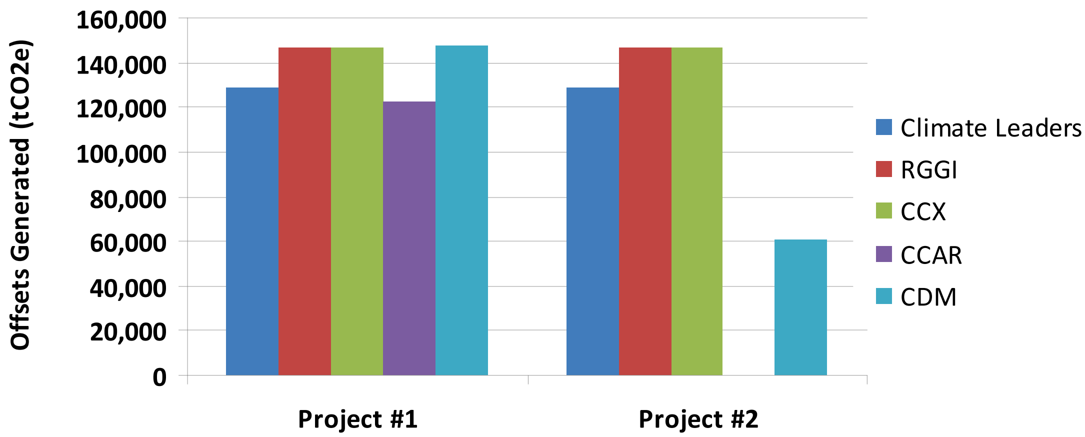

Table 11. Emission Reduction Estimates for Landfill Project #1 (All figures in tCO_2e)

	Climate Leaders	RGGI[29]	CCX	CCAR	CDM
Baseline Emissions (A)	**132,433**	**146,687**	**146,593**	**125,506**	**147,254**
Methane Collected	148,634	148,634	148,634	148,634	148,634
Methane Density Adjustment[30]		3,217	-2,041	352	-1,380
Soil Oxidation	-14,863	-15,185		-14,899	
Destruction Inefficiency	-1,338	-2,733	0	-8,582	0
Methane GWP effect	0	12,755	0	0	0
Project Emissions (B)	**3,284**	**0**	**0**	**2,914**	**0**
Project Energy Emissions(1)	2,914	0	0	2,914	0
Project Related Construction(2)	370	0	0	0	0
Total offsets (A-B)	**129,148**	**146,687**	**146,593**	**122,591**	**147,254**

Note: Blank entries indicate factor/pool not included in protocol; zero indicates factor/pool is included and value is <0.5 tCO2e or not calculated due to lack of data.

For project #2, the differences among protocols are more dramatic, due to the discrepancies noted above in how pre-existing control systems are accounted for. Neither CCX, Climate Leaders, nor RGGI explicitly take into account pre-existing systems, and thus, in such cases, will overestimate emission reductions, assuming the pre-existing systems would have otherwise captured and combusted some or all of the methane combusted by the project. Because the capacity of the combustion system in the sample project exceeded the total amount of methane combusted by the project case, CCAR protocol yields no emission reductions for Project #2. The CDM methodology however does credit the project to the extent that total methane combustion has increased relative to pre-project levels. Implicitly this

[29] All emissions reductions under the RGGI protocol are presented in short tons CO2e, but have been converted to metric tons for the purpose of comparison across protocols.
[30] Relative to Climate Leaders.

methodology presumes that the increase in methane collected and combusted is due to project activities (e.g. improved collection equipment). However, changes in waste flows could also account for differences in methane generation, which would lead to the CDM methodology over or understating baseline emissions (see Table 12).

Table 12. Emission Reduction Estimates for Landfill Project #2 under various protocols (All figures in tCO_2e)

	Climate Leaders	RGGI[31]	CCX	CCAR	CDM
Baseline Emissions (A)	**132,433**	**146,687**	**146,593**	**0**	**60,736**
Baseline Emissions (per Project #1)	132,433	146,687	146,593	125,506	147,254
Deduction for Pre-existing destruction system				-125,506	-86,518
Project Emissions per Project #1 (B)	**3,284**	**0**	**0**	**2,914**	**0**
Total offsets (A-B)	**129,148**	**146,687**	**146,593**	**0**	**60,736**

Note: Blank entries indicate factor/pool not included in protocol; zero indicates factor/pool is included and value is <0.5 tCO2e or not calculated due to lack of data.

3.6 Monitoring

Specific guidelines under each protocol are presented in Table 13. Landfill gas flow rate/quantity and methane gas concentration are required under all protocols through either continuous or at least monthly metering. Only the RGGI, CCX, and CCAR protocols specify that the operational activity must be documented to verify that methane captured was combusted. These same protocols are also the only ones to specify requirements for proper inspection of instruments. CCX, CCAR, and CDM require temperature and pressure data on landfill gas flow or the use of a device that can correct for changes in these parameters.

- LFG Flow Rate: The potential for significant variation in LFG flow on a daily basis, and the widely accepted use of continuous flow meters, suggests that all protocols should require continuous flow monitoring.
- Methane concentration: Protocols differ quite significantly here. RGGI requires continuous monitoring; all other protocols allow project operators to choose between continuous methane analyzers and periodic measurements. Continuous monitoring can yield significantly improved accuracy. As CCAR notes, the methane content of landfill gas captured can vary by more than 20% during a single day due to gas capture network conditions (dilution with air at wellheads, leakage on pipes, etc.). Therefore, CCAR assesses a 10% discount on weekly, and 20% penalty on monthly measurement, to reflect uncertainty.
- Electricity generation alternative: CCX is the only protocol that allows project operators to forego LFG flow and methane concentration monitoring in lieu of inputting methane destruction from the energy output of electricity generation. The method is quite straightforward and

[31] All emissions reductions under the RGGI protocol are presented in short tons CO2e, but have been converted to metric tons for the purpose of comparison across protocols.

inexpensive. As a continuous monitoring method, it avoids the potential errors introduced by periodic flow and concentration monitoring; however, it is quite sensitive to the assumed heat rate (efficiency) of the combustion device.[32]

Table 13. Selected Monitoring Guidelines for Landfill Methane Protocols

Protocol Parameter	Climate Leaders	RGGI	CCX	CCAR	CDM
Landfill gas flow rate	Continuous *or* monthly flow rate metering	Continuous flow rate metering	Continuous flow rate metering	Continuous flow rate metering	Continuous flow rate metering
CH4 gas concentration	Continuous or monthly metering	Continuous metering required	At least monthly; can assume 45% for "early action credits"	Continuous analyzer; weekly measurement (10% penalty); (monthly 20% penalty)	Continuous analyzer or periodic measurements[33]
Alternative to gas flow			Electricity generation and heat rate		
Combustion efficiency	Standard combustion rates per default rate table above				Optional continuous monitoring for closed flare [34]
Energy production	N/A	N/A	Electricity generation of alternative method used	Exported natural gas flow, temperature, pressure, and concentration	Required (if applicable)
Data recording	Documentation in Offset Project Submission Checklist	Documentation in annual report	Monthly record of hours operational	Hourly	
Instrument inspection and calibration of monitoring equipment		Following manufacturer specification	Quarterly/ annual inspection Proof of initial calibration.	Quarterly inspection	"Regular testing and maintenance"
Other	Monitoring of regulatory requirement changes	Annual verification of landfill gas using U.S. EPA laboratory methods			

[32] The heat rate tests should be used if available, but are not required, in which case manufacturer's specifications should be used.
[33] Periodic measurements must meet 95% confidence level
[34] Tool to determine project emissions from flaring gases containing methane, http://cdm.unfccc.int/Reference/tools/ls/meth_tool06_v01.pdf

3.7 Pre-Project ER Estimates

Table 14 presents requirements for pre-project emissions reductions estimates and calculation tools provided by each offset program. Estimates of project emissions before project development are required under the CDM protocols only. Climate Leaders, CCAR, and CDM have developed or suggested tools for estimation: the EPA LandGEM, CARROT and spreadsheet tools, and FOD model respectively. The other protocols include sets of equations to be used for quantification and estimation of emission reductions.

The CCAR methodology is the most conservative methodology for accounting for pre-project control systems, but might be overly so. The CDM methodology could be the most reasonable compromise, given that LFG project could increase the LFG recovery beyond BAU or historical levels.

Table 14. Pre-project emission reduction estimates and calculation tools for Landfill Methane Protocols

Protocol Parameter	Climate Leaders	RGGI	CCX	CCAR	CDM
Estimate Pre-Project Emissions	Not required	Not required	Not required	Not required	Required
Software tool, model, or equations provided?	EPA LandGEM: estimates CH4 emissions. Equations also provided.	Equations for baseline determination and emissions reductions quantification provided.	Equations	CARROT and spreadsheet-based calculation tools	First order decay (FOD) model: estimates emissions by differentiating between waste types, decay rates, and organic carbon fraction

3.8 Conclusions

Landfill methane projects and project protocols are often considered among the most straightforward of offset projects. Since baseline emissions are largely a reflection of methane collected, and similar measurement methods are used across projects and protocols, quantification methodologies tend to yield similar results for landfill projects. However, as the comparisons and road test show, there can be a variation of up to 20% in offsets generated across protocols, under simple and common project circumstances. Under more specialized conditions, e.g. the presence of pre-existing LFG combustion equipment, the differences can be stark.

Based on our review, we have the following observations and recommendations:

- Projects should be eligible to generate offsets up to, but not beyond, the date that a control system is required by regulation. Protocols respond quite differently where changes in regulation or landfill conditions *after initial project verification or registration* trigger legal requirements for the landfill gas control system. Responses range from immediate cessation of eligibility (Climate Leaders) to crediting up to the date the system is required (CCX, CCAR) or until the end of the crediting period

(RGGI, CDM). Given that regulation is already widely in place for landfills and it is relatively predictable when a particular landfill will be required to control its emissions, we would recommend adopting the approach used by CCX and CCAR, i.e. project eligibility until the date an LFG control system is required by regulation.

- Efforts should be undertaken to develop and adopt common default factors for the efficiency of combustion devices (flares, engines, boilers, etc.). The variation among methodologies can lead to differences in crediting that while small (5-10%) should be readily resolved.
- CCAR's requirement that project developers submit a public attestation of regulatory additionality should be adopted widely. This requirement was added in the most recent version (2.0), as verifiers can otherwise find it difficult to execute their responsibilities.
- Continuous LFG flow measurement should be required. This is common practice, and significantly reduces error compared with monthly measurement.
- An uncertainty discount should be adopted for less accurate measurement methods, specifically in the case of less-than-continuous methane concentration measurement.

4 Manure Digester

In 2007, livestock manure management represented about 0.2% of total GHG emissions in the U.S. on CO2e basis, from the emission of methane, and to a lesser extent, nitrous oxide (44 million metric tons CO_2e of CH_4 emissions and 14.7 million metric tons CO_2e of N_2O emissions).[35] While N_2O emissions have remained fairly constant since 1990, a shift toward larger facilities with liquid manure management systems has contributed to a 45% increase in CH_4 emissions from 1990.[36]

The use of biogas control systems, such as anaerobic digesters, can reduce methane emissions from livestock facilities where manure is handled under anaerobic conditions in liquids or slurries. Installations of biogas control systems are not currently required under federal, state or local regulations in the U.S., though in some cases systems are installed as a means of air and water pollution control or for odor reduction.

For each protocol parameter, we first compare the differences among the protocols and then include discussion of how these differences relate to the quantification of the sample projects.

4.1 Descriptions of Sample Projects

We adapted characteristics of two manure digester projects to develop two sample projects that are illustrative of typical project conditions.

Manure Project #1: This sample project is a 550 dairy cow operation in New York State. The dairy operation started in 1993 and installed a conventional anaerobic digester in June 1998. Prior to installing the digester the manure was pumped to a lagoon, where from April to October it was spread daily by trucking it to surrounding fields. During months too cold for spreading, from November to March, it was stored as a liquid/slurry on site until being spread in the spring. The digester was installed for odor reduction and due to concern from the local community regarding transportation of manure. Biogas from the digester is utilized to generate electricity and heat. The remaining solids from the digester are composted and sold to local buyers. The remaining liquids from the digester are irrigated to fields using underground piping and spread by tanker truck.

Manure Project #2: This sample project is a 695 dairy cow operation in Western Washington. The dairy farm has been in operation for over 40 years and installed an anaerobic digester in 2004. Prior to the project installation the manure was separated into solid and liquid streams and the liquids were stored in an anaerobic lagoon from November to February and applied to fields during warmer months from March to October. Biogas generated from the digester is used to generate electricity and heat for on-site use. Solids are separated from the digester effluent and composted.

4.2 Protocols Considered

Each of the five programs considered has issued a manure methane protocol. Many of these protocols have gone through several iterations; comparisons in this report are based on the most recent protocol versions available and may not be applicable to future revised protocol versions issued by these offset programs. The specific protocol names and versions for each of the offset programs evaluated are given in Table 15.

[35] EPA, 2009. Draft Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2007, http://epa.gov/climatechange/emissions/usinventoryreport.html

[36] EPA, 2009. Draft Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2007, http://epa.gov/climatechange/emissions/usinventoryreport.html

Table 15. Manure Methane Protocol Methodologies

	Climate Leaders	RGGI	CCX	CCAR	CDM
Protocol Version Reviewed	Version 1.3, August 2008	RGGI Model Rule (2007)	Chapter 9. CCX Rulebook (2004)	Version 2.1, August 2008	ACM0010/ Version 05 (Valid from Oct. 10, 2008 onwards)
Number of Manure Digester Projects Listed (March 2009)	None	None	>35 registered[37]	2 registered 12 listed[38]	186 registered 330 at validation or reg. request[39]

4.3 Additionality, Regulatory Surplus and Other Eligibility Requirements

Manure methane protocols examined here are applicable to most projects that collect and combust methane from livestock manure. The protocols examined here all credit emissions reduction from the destruction of methane regardless of the destruction technology or ultimate use for energy. Additional specific technologies and conditions for eligibility are presented in Table 16 (bottom row). These differ in several ways across protocols:

- CDM and Climate Leaders protocols specify eligible livestock types.
- RGGI, CCX, and CDM protocols specify that prior manure management practices must have resulted in significant methane emissions due to storage conditions and annual temperatures at the project site.
- CCAR and CDM protocols specify air and water standards that projects must meet.

Emissions reductions from fossil fuel displacement through end use of the collected methane are only credited under two programs: CDM, which includes fossil fuel displacement emissions reductions in its manure methodology; and Climate Leaders, which considers end use of methane in a separate protocol that is not addressed in this study.

New manure methane digester projects meeting protocol start date requirements and not required by regulation are considered additional under the Climate Leaders, RGGI, CCX, and CCAR protocols. Climate Leaders, RGGI, and CCAR each have developed slightly different performance standard approaches, all of which conclude that installation of a new manure digester system exceeds common practice (Table 16).[40] Beyond eligibility requirements discussed above, CCX provides no justification for how manure methane projects demonstrate additionality. The CDM Additionality Tool requires a project-specific additionality test discussed above, with further requirements for investment and barrier analysis. Similarly, RGGI also considers project investment sources by requiring that projects cannot receive support from funds or incentives.

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[37] http://www.chicagoclimatex.com/offsets/projectReport.jsf, accessed on March 26, 2009.
[38] https://thereserve1.apx.com/myModule/rpt/myrpt.asp , accessed on June 15, 2009.
[39] As of March 1, 2009. http://www.cdmpipeline.org/cdm-projects-type.htm. Includes LFG flaring and energy only.
[40] CCAR provides findings suggesting that digesters are found on less than 1% of dairies in California. Climate Leaders findings suggest digesters are found on less than 0.2% of swine operations and 1.7% of dairies. Neither CCAR nor Climate Leaders provide a clear criterion for setting a performance based standard (e.g. market penetration less than X%). RGGI does, requiring that projects occur in states where the market penetration is 5% or less, or on a farm or regional digester that serves 4,000 or fewer animal units.

Regulatory surplus requirements are specified under the Climate Leaders, RGGI, CCAR, and CDM protocols as presented in Table 16. No regulatory surplus requirements are specified for manure methane projects under CCX. Additional distinctions across protocols are bulleted below:

- The specificity of regulatory surplus requirements differs across protocols. Under RGGI, CCAR, and CDM projects are ineligible if the project activity is required by regulation. Under Climate Leaders the requirements appear to permit project activities that go beyond what is required by regulation, that reduce GHG emissions to a level beyond what is required. The Climate Leaders protocol does not provide further guidance on how this would be demonstrated.
- Protocols are not consistent on how changes in regulatory requirements are monitored. Climate Leaders requires monitoring of regulatory changes. Only CCAR requires developers to submit an attestation that no regulations required the project activity.
- The effect of later changes in regulations on projects previously approved under the offset program is not specified by all protocols. RGGI and CCAR specify that the project will only be eligible through the current crediting period. CDM requires that the baseline be adjusted at the start of the next crediting period. Neither CCX nor Climate Leaders specify how this would be handled.

Table 16. Additionality, Regulatory Surplus, and Other Eligibility Requirements of Manure Methane Protocols

Protocol Parameter	Climate Leaders	RGGI	CCX	CCAR	CDM
Additionality Methodology	Practice-based performance threshold.	Must meet either RGGI General Additionality Requirements or project performance threshold Projects are not eligible if support from funds or incentives are provided.	General CCX Guidelines apply	Performance Standard Test.	CDM Additionality Tool
Regulatory Surplus Requirements	Activities must reduce GHG emissions below the level effectively required by any existing federal, state, or local policies, guidance, or regulations. Monitoring of regulatory requirement changes[41]	Activities required by any local, state, or federal law, regulation or administrative or judicial order, are ineligible.	Not specified for this project type	Project developers must submit a signed attestation required stating that there are no state or federal regulations or local agency ordinances/ rulings requiring the project activity	CDM Additionality Tool applies
If digester system is required by regulation after initial approval	Not specified	Eligible through the current crediting period, but cannot be extended.	Not specified	Eligible through crediting period	Adjust baseline at the start of next crediting period
Specific Technologies and Conditions	Dairy and swine waste management systems only	Livestock manure must be >50% of digester feedstock[42] Only organic food waste previously stored in anaerobic conditions may be included	Prior manure management practices must have been through either: liquid/slurry storage; pit storage below animal confinements uncovered anaerobic lagoons	Electricity production and the displacement of fossil fuel power plant GHG emissions are considered to be complimentary and separate activities not included in the protocol accounting. Project must meet local air and water quality regulations	Prior manure management must have been anaerobic for at least 1 month[43] Only manure from cattle, buffalo, swine, sheep, goats, and/or poultry No discharge of manure into natural water resources or ground water Annual avg. temp. must be > 5°C

4.3.1 Implications for Sample Projects

Manure Project #1: Considering project start date requirements alone, project #1 would not be eligible under any of the protocols considered here since it went into operation in 1998. Otherwise, project #1 is generally eligible and considered additional under most protocols.[44] With no existing regulation

[41] Specified as monitoring requirement, not included as a regulatory surplus requirement.
[42] Percent of livestock manure in digester feedstock is only considered under the RGGI protocol.
[43] If present, an anaerobic lagoon must have been at least 1 m^2
[44] Evaluation of select sample project eligibility criteria such as whether the project meets air and water quality regulations is beyond the scope of information available for this report.

requiring digesters, with a prior anaerobic management practice of storing manure in a lagoon/slurry from November to April, project #1 would have been eligible under Climate Leaders, RGGI, CCAR, and CCX. However, since the digester was installed primarily for the purposes of odor control, as with Landfill Project #1 the CDM Executive Board may have questioned whether the offset credits would play any role in overcoming barriers to implementation, and thus reject it.

Manure Project #2: Project #2 would likely be considered additional under all of the protocols evaluated.[45] It was established in 2004 meeting all project start date requirements and was not required by regulation. As with project #1, the prior management practices on the farm would likely have satisfied the Climate Leaders, RGGI, CCX, and CCAR requirements. No information is available on funding sources for the project so it is not clear whether the CDM Executive Board may have questioned whether the generation of offset credits played a role in overcoming barriers to implementation.

4.4 Project Boundary and Leakage

The inclusion and exclusion of emission sources in the manure methane project and baseline activity boundaries vary significantly across the protocols as outlined in Table 17.

- Protocols vary by the GHG covered. Climate Leaders is the only protocol that considers emissions from CO_2, CH_4, and N_2O (direct emissions only) for all activities within the project and baseline boundary.[46] N_2O emissions are not considered under RGGI, CCX, or CCAR. The CDM protocol considers both direct and indirect N_2O emissions, but only for specific activities, which include anaerobic and aerobic baseline manure management, project digester manure management and land application of manure from baseline and project activities. These emissions are captured as part of leakage estimates in the CDM.
- On-site energy use under baseline and project conditions are only included within the project boundary under Climate Leaders, CCAR, and CDM protocols.
- Emissions from transportation in both baseline and project activities are only included in the Climate Leaders and CCAR protocols. RGGI only considers emissions from transportation in project activities for transport of manure to a regional digester.
- Methane emissions from anaerobic manure management under baseline and project conditions are included for all protocols. Baseline emissions from aerobic manure management are only included under Climate Leaders, CCAR and CDM. Project emissions from non-digester manure management of CH4 are only considered by CCAR and CDM and N2O only by Climate Leaders.
- Emissions from digester effluent disposal are only considered within the project boundary under the CCAR protocol. These emissions are captured under the CDM leakage estimate, but are not included in any of the other protocols.
- All protocols, with the exception of CCX and RGGI, consider digester engine/flare collection and destruction efficiency in the project boundary. By excluding collection and destruction efficiency, credits issued by CCX and RGGI do not account for project emissions that would not have occurred in the absence of the project.
- All protocols exclude the following sources/credits from the baseline and project boundary enteric fermentation, emissions from changed fertilizer use, and avoided energy use.

[45] Evaluation of select sample project eligibility criteria such as whether the project meets air and water quality regulations is beyond the scope of information available for this report.
[46] CO2 emissions from baseline and project manure management is the only exclusion.

Table 17. Project and Baseline Activity Boundary for Manure Methane Protocols.

	Physical Boundary and Emissions Sources or Sinks Included	Gas	Climate Leaders	RGGI	CCX	CCAR	CDM
Baseline Activities	**Enteric fermentation**	**All**	N	N	N	N	N
	Emissions from changed fertilizer use	**All**	N	N	N	N	N
	Livestock management (corral/barn)	CO_2	Y (support equipment)	N	N	Y (support equipment)	Y[47]
		CH_4	Y (support equipment)	N	N	N[48]	N
		N_2O	Y (support equipment)	N	N	N	N
	Transportation	CO_2	Y	N	N	Y[49]	N
		CH_4	Y	N	N	N	N
		N_2O	Y	N	N	N	N
	Anaerobic manure management	CO_2	N	N	N	N	N
		CH_4	Y (direct)	Y (direct)	Y	Y	Y
		N_2O	Y (direct)	N	N	N	Y (direct and indirect)
	Aerobic manure management	CO_2	N	N	N	N	N
		CH_4	Y (direct)	N	N	Y	Y[50]
		N_2O	Y (direct)	N	N	N	Y (direct and indirect)[51]
Project Activities	**Enteric fermentation**	**All**	N	N	N	N	N
	Emissions from changed fertilizer use	**All**	N	N	N	N	N
	Livestock management (corral/barn)	CO_2	Y (support equipment)	N	N	Y (support equipment)	Y[52]
		CH_4	Y (support equipment)	N	N	N[53]	N
		N_2O	Y (support equipment)	N	N	N	N
	Biogas control system	CO_2	N	N	N	N	N
		CH_4	Y	N	N	Y	Y
		N_2O	Y (direct)	N	N	N	Y (direct and

47 From use of electricity and heat only

48 CCAR assumes that management would not change due to project, if does (e.g. new feeding system) than this would be incorporated.

49 Vehicle emissions for offsite transport

50 Emissions from land application are outside the project boundary, but are quantified as part of leakage estimate

51 Direct and indirect emissions from land application are outside the project boundary, but are quantified as part of leakage estimate

52 From use of electricity and heat only

53 CCAR assumes that management would not change due to project, if does (e.g. new feeding system) than this would be incorporated.

Physical Boundary and Emissions Sources or Sinks Included	Gas	Climate Leaders	RGGI	CCX	CCAR	CDM
						indirect)
Transportation	CO_2	Y	Y[54]	N	Y	N
	CH_4	Y	N	N	N	N
	N_2O	Y	N	N	N	N
Manure collection system	CO_2	Y[55]	N	N	Y[56]	Y[57]
	CH_4	Y[58]	N	N	Y[59]	Y
	N_2O	Y[60]	N	N	N	N
Digester Effluent Disposal	CO_2	N	N	N	N	N
	CH_4	N	N	N	Y	N[61]
	N_2O	N	N	N	N	N[62]
Non-digester manure management	CO_2	N	N	N	N	N
	CH_4	N	N	N	Y	Y
	N_2O	N	N	N	N	N
Avoided energy use	**all**	N	N	N	N	N
Energy production for export	CO_2	N	Y[63]	N	N	Y[64]
	CH_4	N	N	N	N	N
	N_2O	N	N	N	N	N

The provisions under each protocol for accounting for leakage in manure methane projects are presented in Table 18. RGGI, CCX, and CCAR protocols do not require consideration of leakage for manure methane projects. Both Climate Leaders and CDM protocols include specific methods for quantifying and evaluating leakage for manure methane projects, though the approach differs between the protocols. Quantification of leakage under the Climate Leaders protocol is limited to project emissions from fossil fuel use for activities that are outside of the project boundary. Consideration of leakage under the CDM protocol is restricted to the quantification of the net increase in CH_4 and N_2O emissions from land application of treated manure under the project relative to the baseline scenario.

[54] Emissions associated with transport of manure to a region digester only
[55] Emissions associated with operation and construction of system only.
[56] From energy usage for system operation
[57] From electricity consumption for system operation
[58] Emissions associated with operation and construction of system only.
[59] Includes non-combusted/leaked gas
[60] Emissions associated with operation and construction of system only.
[61] Emissions from land application are outside the project boundary, but are quantified as part of leakage estimate
[62] Direct and indirect emissions from land application are outside the project boundary, but are quantified as part of leakage estimate
[63] Only in cases where project sponsor transfers legal rights to any and all attributable credits for use with an RPS to the regulatory agency
[64] Emissions from electricity and thermal energy generation

Table 18. Leakage Provisions for Manure Methane Protocols

Protocol Parameter	Climate Leaders	RGGI	CCX	CCAR	CDM
Leakage	Consideration and quantification of emissions from leakage required.	Not considered	Not considered	Not considered	Consideration and quantification of emissions from leakage required.

Implications of different boundary conditions and leakage considerations for sample projects are best illustrated in the following quantification section.

4.5 Baseline Determination and Quantification of Emission Reductions

Baseline scenarios for all of the U.S. based protocols are based on the emissions from the prior management activity before or in absence of the project. CDM requires the identification of the baseline scenario through a series of steps including the identification of realistic and credible alternative scenarios to the proposed activity followed by barriers and investment analysis of each baseline scenario alternative (See further discussion in Section 2). Under the CDM protocol, the project is considered additional if the baseline determination demonstrates that the baseline is different from the proposed project activity not undertaken as a CDM project activity.

The overall approach for quantifying baseline and project emissions is similar across manure methane protocols. In all cases, emissions are the sum of sources included in the baseline and project boundary minus emissions from leakage if considered. Substantial differences in the boundaries of baseline and project activities across protocols, discussed above, are reflected in variations in quantification of baseline and project emissions.

Comparison of baseline emissions quantification across protocols:

- CH_4 emissions from anaerobic baseline manure management systems are included under all protocols.
- CH_4 emissions from aerobic manure baseline management systems are only included under Climate Leaders, CCAR, and CDM.
- N_2O emissions from baseline manure management are only included under Climate Leaders and CDM.
- Fossil fuel emissions from baseline manure management are only included under Climate Leaders, CCAR, and CDM protocols.

Comparison of project emissions quantification across protocols:

- CH_4 emissions from project digester manure management including non-combusted and leaks in the collection system are included under all protocols, except for CCX and RGGI.
- CH_4 emissions from project non-digester manure management systems are only included under CCAR and CDM.
- N_2O emissions from project manure management are only included under Climate Leaders and CDM.

- Fossil fuel emissions from project manure management are only included under Climate Leaders, RGGI, CCAR, and CDM protocols. Fossil fuel sources included vary by protocol, e.g. RGGI only includes emissions from transportation of manure to a regional digester, see project boundary discussion above for all variations.
- CH_4 emissions from digester effluent are only considered under the CCAR protocol. Land application of digester effluent is considered under the quantification of leakage under the CDM protocol.

Comparison of approach to baseline and project emissions quantification:

- Protocols differ in their approach to quantifying methane emissions from manure. Climate Leaders, CCX, and CDM use manure management system and climate specific default methane conversion factors (MCF). RGGI and CCAR protocols use monthly average temperatures at the project site to calculate the Van't Hoff-Arrhenius factor and determine the conversion efficiency of volatile solids to CH_4.
- Protocols differ in the approach to quantifying volatile solids production. Climate Leaders, CCX, CCAR, and CDM estimates are based on default or project-specific data of volatile solids produced per animal scaled by the population of animals. The RGGI protocol uses farm data on total manure production multiplied by the concentration of total solids and the concentration of volatile solids in total solids based on testing of manure from the project site. The concentrations of total solids and volatile solids could vary due to uncertain farm operations such as how much water is used to flush out manure from holding pens into the slurry pit.
- Protocols differ in the approach to quantifying emissions in cases where more than one management system is used. RGGI, CCX, CCAR, and CDM allow the fraction of manure managed by a given system to be adjusted to reflect different management systems. Climate Leaders includes the sum of emissions from each management system, but assumes that system type is varied by animal unit numbers when practices may instead vary across a calendar year or other form.
- Emissions from leakage are only considered under the Climate Leaders and CDM protocols. Though as discussed in the section above, sources of leakage are entirely different between these two protocols.
- Data value inputs that differ across protocols are presented in Table 19. Variations in methane GWP, combustion efficiency, and CH_4 density default values follow differences discussed in landfill methane projects, see discussion in section above. Protocols differ on the degree to which they require values verified from the project or permit the use of default values. The MCF default values under Climate Leaders are based on the GHG inventory, which is based on 2006 IPCC Guidelines. CDM MCF factors incorporate a 94% conservativeness factor. Biogas collection efficiency, a large contributor to total project emissions is 99% under the Climate Leaders, but default values of 85% (unless verified otherwise) are used for CCAR and CDM protocols. Neither RGGI nor CCX calculate project emissions, for both protocols collection efficiency is assumed to be 100%.

Table 19. Comparison of Default Values

Data Parameter	Climate Leaders	RGGI	CCX	CCAR	CDM
Average monthly temperatures (°C)	N/A	As verified	N/A	As verified	N/A
Average mass of livestock (kg)	As verified	As verified	Default	As verified	As verified
Volatile solids (kg VS/day/1000kg)	Default or as verified	N/A	N/A	Default	Default or as verified
Maximum methane production capacity (m^3 CH_4 /kg VS)	Default or as verified	Default or as verified	N/A	Default	Default
Methane conversion factor (MCF)					
daily spread	0.1%	N/A[65]	N/A[66]	0.1%	0.09%
liquid slurry	17%	N/A	N/A	N/A[67]	16%
anaerobic lagoon	66%	N/A	N/A	N/A	62%
Biogas collection efficiency	99% (varies by digester type)	100% (implicit)	100%	85% or as verified	85% or as verified
Biogas destruction efficiency	99%	100% (implicit)	100%	98% or as verified	90% or as verified
GWP of CH_4	21	23	21	21	21
GWP of N_2O	310	N/A	N/A	N/A	310

4.5.1 Implications for Sample Projects

Quantification of baseline emissions, project emissions, and emissions reductions credited for sample projects under the various protocols are included in the tables and figure below. Quantification of emissions reductions from project #1 are shown in Table 20 and from project #2 in Table 21. Figure 3 provides a summary graph of emissions reductions credited (offsets awarded) for project #1 and #2 under the various protocols.

[65] RGGI uses the Van't Hoff-Arrhenius factor instead of MCF factors to calculate manure emissions, so no MCF factors are presented in this table.

[66] CCX provides default tables of methane emissions factors for livestock category, manure management system, and state (kg CH_4/head per day)

[67] CCAR, except in the case of aerobic manure management, uses the Van't Hoff-Arrhenius factor instead of MCF factors to calculate manure emissions, so no MCF factors are presented in this table for those management systems.

Table 20. Quantification of Manure Methane Sample Project #1 (All figures in t CO_2e)

<table>
<tr><th></th><th>Climate Leaders</th><th>RGGI[68]</th><th>CCX</th><th>CCAR</th><th>CDM</th></tr>
<tr><td>Baseline Emissions (A)</td><td>337</td><td>466</td><td>309</td><td>395</td><td>358</td></tr>
<tr><td>Anaerobic treatment (CH4)</td><td>271</td><td>466</td><td>309</td><td>384</td><td rowspan="2">271</td></tr>
<tr><td>Aerobic treatment (CH4)</td><td>2</td><td></td><td></td><td>2</td></tr>
<tr><td>Anaerobic treatment (N_2O)</td><td>57</td><td></td><td></td><td></td><td rowspan="2">86</td></tr>
<tr><td>Aerobic treatment (N_2O)</td><td>0</td><td></td><td></td><td></td></tr>
<tr><td>Mobile fossil fuel use</td><td>9</td><td></td><td></td><td>9</td><td></td></tr>
<tr><td>Stationary fossil fuel use</td><td>0</td><td></td><td></td><td>0</td><td>0</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Project Emissions (B)</td><td>131</td><td>0</td><td>0</td><td>805</td><td>1145</td></tr>
<tr><td>Biogas control system(CH4)</td><td>75</td><td>0</td><td>0</td><td>732</td><td>923</td></tr>
<tr><td>Non-digester manure treat. (CH4)</td><td></td><td></td><td></td><td>0</td><td>0</td></tr>
<tr><td>Digester effluent (CH4)</td><td></td><td></td><td></td><td>17</td><td></td></tr>
<tr><td>Biogas control system (N_2O)</td><td>0</td><td></td><td></td><td></td><td>86</td></tr>
<tr><td>Digester effluent (N_2O)</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Mobile fossil fuel use</td><td>0</td><td></td><td></td><td>0</td><td>0</td></tr>
<tr><td>Stationary fossil fuel use</td><td>56</td><td></td><td></td><td>56</td><td>56</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Leakage (C)</td><td>8</td><td></td><td></td><td></td><td>0</td></tr>
<tr><td>Fossil fuel use</td><td>8</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Land application of manure</td><td></td><td></td><td></td><td></td><td>0</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Total offsets (A-(B+C))</td><td>198</td><td>466</td><td>309</td><td>0</td><td>0</td></tr>
</table>

Note: Blank entries indicate factor/pool not included in protocol; zero indicates factor/pool is included and value is <0.5 tCO2e or not calculated due to lack of data.

[68] All emissions reductions under the RGGI protocol are presented in short tons CO2e, but have been converted to metric tons for the purpose of comparison across protocols.

Figure 3. Estimated offsets for sample manure digester projects under various protocols

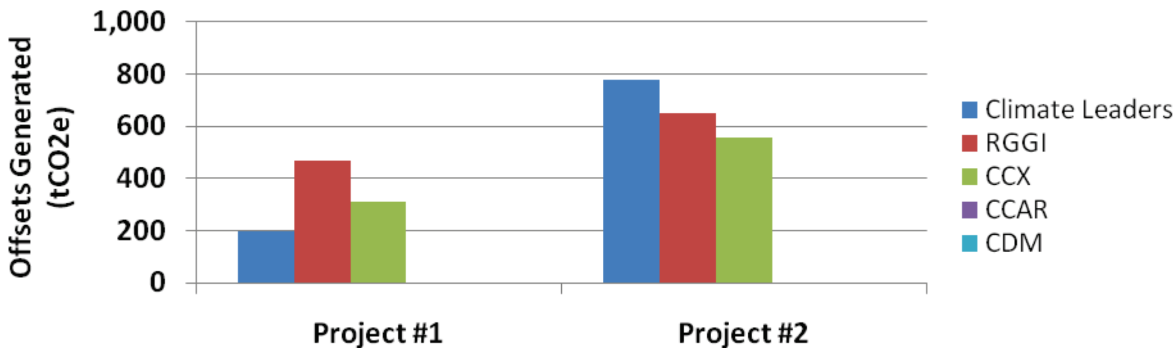

Table 21. Quantification of Manure Methane Sample Project #2 (All figures in tCO_2e)

	Climate Leaders	RGGI[69]	CCX	CCAR	CDM
Baseline Emissions (A)	**1074**	**650**	**556**	**340**	**1410**
Anaerobic treatment (CH4)	1609	650	556	532	1682
Aerobic treatment (CH4)	5			5	
Anaerobic treatment (N_2O)	91				186
Aerobic treatment (N_2O)	91				
Mobile fossil fuel use	0			0	
Stationary fossil fuel use	0			0	0
Project Emissions (B)	**298**	**0**	**0**	**2522**	**2968**
Biogas control system(CH4)	298	0	0	761	2174
Non-digester manure treat. (CH4)				0	0
Digester effluent (CH4)				1761	
Biogas control system (N_2O)	0				186
Digester effluent (N_2O)					
Mobile fossil fuel use	0			0	
Stationary fossil fuel use	0			0	0
Leakage (C)	**0**				**2480**
Fossil fuel use	0				
Land application of manure					2480[70]
Total offsets (A-(B+C))	**776**	**650**	**556**	**0**	**0**

Note: Blank entries indicate factor/pool not included in protocol; zero indicates factor/pool is included and value is <0.5 tCO2e or not calculated due to lack of data.

[69] All emissions reductions under the RGGI protocol are presented in short tons CO2e, but have been converted to metric tons for the purpose of comparison across protocols.

Quantification of sample project total emissions reductions illustrates several distinctions across protocol quantification methodologies:

- Protocols differ in the approach to calculating of total emission reductions:
  - CCX is the only protocol that uses the lesser of either the methane collected and destroyed as measured by the flow meter from the digester or a calculation of baseline emission to determine total emission reductions.
  - RGGI, Climate Leaders, CCAR, and CDM all determine emissions reductions based on the difference between baseline (pre-project) and project emissions. RGGI only considers project emissions from transportation of manure to regional digesters. Climate Leaders and CDM also subtract leakage emissions. All protocols but for Climate Leaders include a provision that baseline emissions must not exceed CH_4 captured/destroyed from the digester.
- Baseline CH_4 emissions vary depending on quantification approach. CCAR and RGGI protocols use the Van't Hoff-Arrhenius factor to determine the conversion efficiency of volatile solids to CH_4, while default factors for methane emissions are used by Climate Leaders, CCX and CDM protocols. Climate Leaders and CDM MCFs are based on annual average temperature and management type, while CCX provides look up tables by U.S. state, livestock category and management type. Baseline CH_4 emissions, for each sample project, are most similar across protocols using the same quantification approach (e.g. Climate Leader and CDM have similar estimates, as well as RGGI and CCAR). RGGI uses a GWP of 23 instead of the value of 21 used by all of the other protocols; this contributes to the larger CH_4 emissions relative to CCAR. Interestingly, in project #1 estimates based on MCFs (Climate Leaders, CDM, and CCX) were lower than those using the Van't Hoff-Arrhenius factor (RGGI and CCAR); while in project #2 the opposite was true. Higher MCF factors were used in project #2 based on baseline manure storage in an anaerobic lagoon vs. liquid/slurry, yet this difference in baseline management treatment system is not captured in the calculation using the Van't Hoff-Arrhenius factor. These differences in CH_4 emissions from anaerobic manure management drive differences in baseline emissions across protocols.
- Digester effluent. Emissions from digester effluent are only considered under the CCAR and CDM protocols though both consider emissions using different approaches. Under the CCAR protocol only CH_4 emissions from management of digester effluent are considered and quantification is dependent on the management approach applied at the project. Sample project data reflects that for project #1 effluent was composted and in project #2 effluent was held in a lagoon. Under CDM N_2O and CH_4 emissions only from land application of digester effluent are considered in the quantification of leakage. For both sample projects the emissions from digester effluent under the CCAR and CDM protocols were large relative to other sources considered. Although Climate Leaders and CDM use a similar approach to quantifying several project emissions sources, the emissions from leakage quantified under CDM is a primary driver of differences between the quantities of offset credits generated between these two protocols.

- CH_4 emissions from the biogas control system. Protocols differ in the biogas collection efficiency value used for biogas control systems. Climate Leaders provides a look-up table to determine the value based on digester type, CCAR and CDM require verified project values or use a default value of 85%. In both sample projects, Climate Leaders assigns a collection efficiency of 99% for the plug-flow digesters used, but the default value was used for CCAR and CDM protocols. As a result, CH_4 project emissions were much larger under the CCAR and CDM protocols.
- Emissions from aerobic manure management. Both sample projects daily spread manure on fields for a large portion of the year, limiting the time that manure is stored in anaerobic conditions. Emissions from the aerobic management of manure under the baseline conditions were only quantified under Climate Leaders, CCAR, and CDM protocols. For all protocols, emissions from aerobic treatment made up a very small portion of the overall CH_4 emissions from baseline manure management.
- Emissions from non-digester manure management. In contrast to the baseline CH_4 emissions where Climate Leaders, CCAR, and CDM consider alternatives to anaerobic manure management, only CCAR and CDM include CH_4 project emissions from non-digester manure management. This distinction is not reflected in the sample projects, because in both cases all manure under the project activity was management using the digester.
- N_2O emissions. Only Climate Leaders and CDM protocols included N_2O baseline and project emissions. For both sample projects the N_2O emissions are larger under the CDM vs. the Climate Leaders protocols, which reflects that CDM includes both direct and indirect sources. Although N_2O emissions do vary by manure management system type, for both sample projects N_2O emissions were small relative to CH_4 emissions for the baseline and project activities.
- Fossil Fuel Use. Climate Leaders and CCAR include emissions from mobile and stationary fossil fuel sources, while CDM only considers heat and electricity use. While both sample projects used electricity prior to the project and generated electricity from the project manure digester, in neither case was electricity production, on-site use, and off-site production data available; so these emission sources are not captured in results presented here. In sample project #1 the quantification under Climate Leaders and CCAR reflects baseline diesel fuel use to transport manure off-site to be field spread. Under the project activities propane use for digester is captured under Climate Leaders, CCAR, and CDM protocols. No fossil fuel use was known or included in estimates of project #2. Emissions from fossil fuel use for project #1 were small relative to other emissions sources.
- Not all features of projects are well captured by protocols. Only the CCAR protocols includes a range of potential management options with digester effluent and thereby captured that under project #1 digester effluent was composted. Only CCX includes provisions to account for solids separation of manure under baseline manure management under project #2.

4.6 Monitoring

Specific monitoring guidelines required under each protocol are presented in Table 22. All protocols require biogas control system flow rate and CH_4 concentration. Though, the frequency of metering biogas flow rate and concentration varies substantially across programs.

- Biogas flow rate. Climate Leaders and RGGI permit monthly measurement, CDM permits weekly measurement, and both CCX and CCAR require continuous metering. As discussed above for landfill methane projects variations in flow rate can be significant supporting the use of continuous metering.

- Methane concentration. Climate Leaders and RGGI permit monthly sampling, CDM permits weekly, CCAR permits quarterly, and CCX annually. As discussed above for landfill methane projects, variation in flow rate can be significant, supporting the use of continuous metering.

CCAR is the only protocol to require monitoring of both the operation of the biogas control system and inspection of biogas instruments. CCX does require quarterly inspection of the flow rate meter. Climate Leaders and CCX provide limited additional monitoring guidance. In contrast RGGI, CCAR, and CDM include all data parameters needed for emission reduction calculations in the monitoring requirements.

Table 22. Monitoring Guidelines for Manure Methane Protocols

Protocol Parameter	Climate Leaders	RGGI	CCX	CCAR	CDM
Biogas control system flow rate	Continuous or monthly metering	Monthly metering	Continuous flow rate metering	Continuous metering	Continuous or weekly metering
CH_4 **gas concentration**	Continuous or monthly metering	Monthly metering	Default factors with annual sample analysis or hourly averaged measurements	Quarterly metering	Continuous or weekly metering
Alternative to gas flow			Electricity generation and heat rate		
Operational monitoring	-	-	-	Hourly	-
Instrument Inspection	-	-	Minimum of quarterly inspection of flow meter	Bi-annual calibration	-
Additional guidance available?	-	Additional input monitoring requirements[71] Annual monitoring and verification reports	-	Additional direct measurements[72]	Additional direct measurements[73]

[71] Includes average monthly temperature from the nearest Natl. Weather Service Station, monthly influent flow, digester influent flow, livestock population, monthly influent % total solids, and monthly % volatile solids.
[72] Includes environmental regulations, livestock categories, fraction of manure managed by each treatment system, animal population by livestock category, live weight of livestock by category, biogas temperature, biogas pressure, biogas destruction efficiency, biogas collection efficiency, and quantity of fuels used for mobile/stationary combustion sources.
[73] Include annual average temperature, demonstration of existence and enforcement of relevant regulations, daily stock of animals in barn, energy density of feed, ash content of manure as a fraction of dry matter feed, volatile solid excretion per animal per day, type of barn and manure management system, crude protein percent, gross energy intake of animal, electricity exported to grid, number of days animal is alive at farm, number of animals produced annually, average animal weight, and fraction of volatile solids directed to digester and aerobic treatment.

4.7 Pre-Project Emission Reduction Estimates

Protocol requirements for pre-project emission reduction estimates, as well as quantification tools available, are presented in Table 23. Estimation of pre-project emissions is not required under Climate Leaders, CCAR, or CCX. All protocols provide equations and default values (for specific data parameters) for quantifying emissions reductions. Climate Leaders indicates that AgSTAR FarmWare 3.0 can be used for quantification. CCAR has developed an online excel based calculation tool. No other protocols have software or modeling quantification tools available.

Table 23. Pre-project emission reduction estimates and calculation tools for Manure Methane Protocols

Protocol Parameter	Climate Leaders	RGGI	CCX	CCAR	CDM
Estimate Pre-Project Emissions	Not required	Baseline determination only	Ex-ante calculation of baseline emissions (optional)	Not required	Baseline determination only
Software tool, model, or equations provided?	Equations and default values AgSTAR FarmWare 3.0 can be used	Equations and default values	Equations and default values	Equations and default values Online Excel based calculation tool Version 2.1.1	Equations and default values

4.8 Conclusions

Based on our review of manure methane protocols across various protocols and on road-testing with sample projects, we recommend:

- adopting CCAR's requirement that project developers submit a public attestation of regulatory additionality, as with landfill methane protocols.
- allowing projects to generate credits for their entire crediting period, even if new emission control rules are enacted during the crediting period, as this would provide an incentive for early action to control emissions. Our recommendation here differs from that for landfill project because the regulation of manure emissions is far less common or predictable.
- additional research to validate the methods commonly used to quantify baseline methane emissions from manure management activities, and, if appropriate, develop alternative methods. Since we did not undertake a scientific analysis, our assessment of sample projects in this report provides no clear indication of the accuracy of the two predominant methods (the use of default annual methane conversion factors (MCFs) and application of the van't Hoff-Arrhenius factor).
- inclusion of the full suite of potentially significant project emissions. For example, only CCAR and CDM protocols include projects emissions from digester effluent, which can be large as in the case of the sample projects considered here. CCX and RGGI assume 100% collection and destruction efficiency of biogas, which could overstate emission reductions. Climate Leaders include nitrous oxide but not methane emissions from non-digester manure management.
- further assessment of baseline (and project) nitrous oxide emissions from field spreading of manure (and digester effluent), which could be quite significant but is subject to considerable uncertainty. In some project circumstances, e.g. where field spreading is the baseline

management method, nitrous oxide from field spreading can be the single largest source of baseline emissions. Counting this source can mean the difference between generating offset credits and not doing so.

- inclusion of provisions that baseline CH_4 emissions cannot exceed the quantity of CH_4 captured and destroyed by the project digester. Digesters, which are typically engineered and operated to maximize methane production, will tend to produce more methane than pre-project management systems, such as lagoons. Currently, RGGI, CCAR, and CDM all include such a provision, which guards against over-crediting.
- further specification of monitoring requirements. In order to verify that CH_4 captured by the digester is being destroyed and flared as CO_2, protocols could consistently include monitoring requirements, similar to those of CCAR, for the operation of the manure digester/flare and inspection of biogas instruments.

5 Afforestation/Reforestation (A/R)

Afforestation and forest management are widely considered to be the largest potential sources of domestic offsets under a potential cap-and-trade system in the U.S.[74] However, forestry is a relatively low value use of land, and the potential supply of forest offsets is strongly influenced by other non-forestry demands for land[75] as well as policies defining what carbon sequestration activities can be counted as offsets.

This analysis applied five different accounting protocols for afforestation projects to two sample projects in order to assess offsets credited and to identify the main reasons for variations observed.

5.1 Description of Sample Projects

The two projects assessed in this study are both afforestation projects. The projects are:

- Project #1: Restoration of degraded forest land in the dry interior Pacific Northwest
- Project #2: Conversion of agricultural land to pine plantation in the Southeast

A/R Project #1: The Pacific Northwest project restores Ponderosa Pine to an area that had been old-growth Ponderosa Pine (*Pinus ponderosa*) at the time Europeans occupied the area. Over decades, the highest-value remaining trees were repeatedly removed. With fire suppression and removal of pines, the forest tree species composition shifted to dominance of White Fir (*Abies concolor*) in much of the project area. The trees became dense and stressed by competition and were invaded by insects that killed most of the White Fir. At the same time, intensive cattle grazing killed many of the regenerating pine seedlings that might have re-colonized the area in the absence of grazing. A new owner purchased the property and implemented the restoration project. The restoration project included complete removal of cattle from some portions of the lands and substantial reduction of cattle numbers or removal for several years on the rest of the project land area. The project activities also include planting of pine.

Because the project was established less than 10 years ago, trees on the actual project lands have not grown to maturity. For the purposes of this analysis, actual measurements of tree species and density have been extrapolated to estimate the tree sizes, density (and variability in sizes and density) that might be present in year 50 of the project. These extrapolated trees have been used to calculate the cumulative offsets at year 50. Growth of the trees and variability in their sizes were calibrated using measurements of similar forest stands in the area. This project includes no harvesting because under the actual site conditions the forest grows slowly and a clear-cut rotation length would be approximately 75 years, which is beyond the timescale considered. The analysis assumes that thinning and natural mortality remove as many trees as are added over the life of the project through natural regeneration.

A/R Project #2: The Southeastern afforestation project involves establishment of trees on agricultural land, and intensive forest management, with clear-cutting every 20 years (no thinning). This analysis assumes growth and yield values calculated for an actual property in northern Florida. The offsets are calculated for year 40 of the project. This project duration illustrates how inclusion of harvesting into an afforestation project affects the total number of offsets and when the offsets accrue. Harvesting is likely to be included in many afforestation projects because integrating harvest can give a greater return on investment than afforestation without harvest. To avoid having the project's live tree biomass reduced

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[74] EPA Analysis of the Lieberman-Warner Climate Security Act of 2008, http://www.epa.gov/climatechange/downloads/s2191_EPA_Analysis.pdf.

[75] Fawcett, Allen, 2008. *Offsets in E.P.A. Analyses of S.2191, S.1766, and S.280.* Presentation at EPRI GHG Emissions Offsets Workshop. June 26, 2008. Washington, DC.

to zero every 20 years at the time of clear-cut harvest, it is assumed that the project encompasses 20 acres with one acre converted to forest each year for 20 years. This staggered planting results in staggered harvest, where the live tree biomass rises for the first 20 years and then remains constant. Woody debris carbon rises after harvest and then approaches equilibrium, and carbon on harvested wood products is still rising at the 40 year time used for this analysis.

5.2 Protocols Considered

This study road-tests five methodologies for quantifying the GHG benefits of afforestation: Climate Leaders, RGGI, CCX, CCAR, and CDM. The versions of the tested protocols are noted in Table 24. Attributes of each methodology are described in the sections below. All of these methodologies are sector-specific guidance to be used under general program accounting rules.

Afforestation/Reforestation projects registered as of March 2009 are presented in Table 24. No A/R projects have been registered under using the Climate Leaders, CCAR, or RGGI methodologies. More than 25 forestry projects have been registered under CCX. This analysis did not determine how many of these projects are afforestation versus forest management or avoided deforestation, but the information reviewed indicates that a substantial proportion are afforestation projects. CCAR has forestry projects registered, but these are forest management and avoided deforestation projects, not afforestation projects. CDM has 39 A/R projects in the process of being validated or registered.

Table 24. Afforestation Accounting Methodologies and Projects Registered

	Climate Leaders	RGGI	CCX	CCAR	CDM
Protocol Version Reviewed	Version 1.3 August 2008	RGGI Model Rule (revised December 2008)	CCX Afforestation Verification Guideline Document (April 25, 2008)	Revised Forest Project Protocol Draft: December 2008	AR-ACM001/ Version 3, Afforestation of degraded land
Number of Afforestation Projects Listed (March 2009)	None	None	>25 forestry projects registered; not determined how many of these are afforestation[76]	No afforestation projects listed[77]	0 registered 39 at validation or reg. request[78]

5.3 Additionality, Regulatory Surplus and Other Eligibility Requirements

All the methodologies except CCX require that the carbon sequestered be above and beyond sequestration that would occur under applicable laws and regulations.[79] CCX is silent with respect to additionality or being surplus to law or regulation. Except for Climate Leaders, the methodologies are vague or silent with respect to contractual obligations that require the project activity. Climate Leaders raises the issue of conservation contracts, but does not rule on the admissibility or non-admissibility of projects where lands were previously enrolled in the U.S. Conservation Reserve Program or a similar

[76] http://www.chicagoclimatex.com/offsets/projectReport.jsf, , accessed on March 26, 2009.
[77] https://thereserve1.apx.com/myModule/rpt/myrpt.asp , accessed on March 26, 2009.
[78] As of March 1, 2009. http://www.cdmpipeline.org/cdm-projects-type.htm. Includes LFG flaring and energy only.
[79] Applicable laws and regulations could be climate related but more likely would be air pollution or land use related, such as criteria pollutant, water protection, or forestry regulations.

program. Regulatory surplus and additionality requirements for each methodology are presented in Table 25.

This table also describes the differing eligibility requirements. All methodologies considered here are limited in applicability to projects on land that has been under non-forest cover for several years. Required duration of time out of forest varies across the programs, and each program specifies how soon after project implementation projects must seek verification to be granted recognition by the program. Details are summarized in Table 25**.**.

All methodologies are intended to recognize only results of specific project actions and not natural regeneration that would occur under continuation of pre-project management activities.

Project location and start date restrictions under each methodology are consistent with general offset program features discussed above.

Table 25. Additionality, Regulatory Surplus, and Other Eligibility Requirements of A/R Protocols

Protocol Parameter	Climate Leaders	RGGI	CCX	CCAR	CDM
Regulatory surplus requirements	Required restoration after surface mining under federal regulation not eligible	RGGI General Additionality Requirements apply	Not addressed	Required	CDM Additionality Tool applies and includes regulatory surplus requirement
Requirements related to other requirements or incentives	No guidelines yet established to address regulatory surplus of CRP & similar programs	May not be registered in another GHG program	Not addressed	Not addressed	Implicitly addressed in additionality determination
Additionality methodology	Practice-based performance standard	Only regulatory surplus and project not receiving credits under another system	None	Qualitative requirement that sequestration must be beyond business-as-usual	CDM Additionality Tool: Start date after 1989, plausible alternative baseline, investment or other barrier, and not common practice
Specific additionality thresholds or standards	Low baseline afforestation rate documented in the RAPCOE tool used as evidence that afforestation is not common practice	None	None	Baseline modeled and net sequestration beyond baseline considered additional	Site-specific analysis of project and alternative baseline(s)
Eligibility/ Applicability	Afforestation or reforestation of U.S. crop or pasture land from non-forest to forest use	Conversion of land in RGGI states, or states with a MOU with a RGGI state, that has been non-forested for at least 10 years to forested condition	Afforestation of U.S. and specified non-U.S. lands that have been degraded or un-forested since Dec. 31, 1989.	Establishment and maintenance of native tree cover on U.S. lands not under forest for the previous 10 years	Afforestation and reforestation degraded former forest in any country that does not have a Kyoto Protocol emission limit[80]
Technologies, Conditions	Privately-owned cropland or pasture only Projects must start after February 20, 2002 Project life not currently addressed	Project must start after December 20, 2005 Plantings must be native species and management must conform to a U.S. sustainable forestry system[81]	Harvesting or thinning not permitted, however project can be converted to a forest management project where harvesting is permitted	Pre-project, lands must have less than 10% tree canopy cover Appropriate tree species for native forest type and soils required Minimum proportion of mature forest specified as function of culmination of mean annual increment	Project action may be planting or removal of grazing to allow natural regeneration

[80] CDM currently has 11 approved afforestation-reforestation methodologies, including two consolidated methodologies. Consolidated methodologies are generalized to be widely applicable and this methodology was selected for analysis because it is the most broadly applicable of the two consolidated methodologies.

[81] Certification of management required to be through the Forest Stewardship Council, Sustainable Forestry Institute, American Tree Farm System or other similar organization.

5.3.1 Implications for Sample Projects

Both sample projects demonstrate that they are surplus to regulations. Therefore, both projects would meet the regulatory surplus requirements for these methodologies.

The sample projects meet the additionality requirements of all the methodologies analyzed in this study. Afforestation is not common practice in the U.S. Removing grazing from the PNW site would forego current revenue. Investment analysis conducted as a part of this road-test shows that at a 6% annual discount rate, which is conservative for private investments, the present value of timber revenues is much less than the cost of planting, for both projects. Adding the costs of land and maintenance would make returns significantly more negative. Including tax benefits of forestry would provide some financial benefits, but tax benefits are expected to be less than land and maintenance costs.

Curiously, under strict interpretation of program guidelines, the PNW restoration project probably would not be eligible under any of the programs except Climate Leaders and CCAR, because the major insect mortality occurred in the 1990s, and the project area had substantial tree cover on January 1, 1990. However, the project is analyzed as if it would count, to illustrate the effects of accounting rules on offset counts. The SE afforestation project appears to qualify under all Climate Leaders, CCX and CCAR.

The sample projects are on private land that was previously degraded or under annual cropping, and thus are eligible to create offsets under all methodologies. Grazing and insect disturbance must be invoked for the PNW restoration project to be eligible under CCAR, and the project would only count under CDM if one accepts that ongoing grazing would prevent natural recovery of the lands.

Although technically neither project meets the project location requirements for CDM or RGGI, for the purposes of comparison both projects are quantified as if they qualified under all methodologies tested.

It is open to interpretation whether the timing and degree of degradation would qualify the PNW project under RGGI, because it was less than ten years from the time of the removal of the insect-killed trees to the date of the start of the project. Also, the project was initiated prior to 2005 and thus would be ineligible under RGGI. The final insect disturbance episode occurred after January 1, 1990, so the project would not be eligible under CCX.

This analysis assumes that when harvesting commences on the SE afforestation project the project would be converted to a forest management project under CCX, and CCX large-project forest management rules would apply (although, to make the project easy to understand, the numbers are calculated as if the project is only 20 acres).

5.4 Project Boundary and Leakage

The methodologies all define the project boundary as encompassing the lands where project activities are implemented. CCAR and CDM require consideration of the entire ownership, tracking harvests on the ownership as a whole, and during offset calculations increased harvest elsewhere on the ownership is subtracted from sequestration achieved within the planted area.

For afforestation projects, typically, the vast proportion of carbon stock change is from an increase in tree biomass. Fuel emissions are almost always very small relative to sequestration. Shrub, litter, and soil carbon stock changes are nearly always negligible or positive for afforestation projects, unless there is a great deal of soil disturbance in site preparation or drainage of organic soils. Relatively few projects use fertilizer, but if fertilizer is used its emissions can cancel out several percent of the biomass sequestration. Baseline woody debris stocks are nearly always negligible, and may remain small or become significant, depending on what happens to live trees that grow on project lands.

The programs have wide variation in the list of carbon pools and GHG fluxes that are included in the project boundary. CCAR is the most comprehensive in terms of required pools. All forest C pools are required as well as a wood products pool. Climate Leaders is the next most comprehensive in terms of requirements, including all forest C pools but not HWP. RGGI and CDM both have a number of optional or conditional pools. All programs require including of aboveground live tree biomass, but the commonality ends there. Climate Leaders, CCX, and CCAR are prescriptive as to which carbon pools will and will not be counted. RGGI gives no guidance regarding when to include or exclude option carbon pools, leaving the decision to the project developer. CDM requires counting the conditional pools unless information indicates that GHG benefits of the project would be understated by excluding a pool from the accounting. Table 26 summarizes the pools and fluxes included in default counts under each methodology.

Actual pools and fluxes included in the project boundary may be quite different from the default pools and fluxes to be included. CCAR and CDM allow exclusion of the smallest fluxes, up to 5% of the total estimated net sink. CDM uses IPCC default emission factors to estimate the sizes of fluxes for determination of whether these fluxes can be excluded. Particular stocks can be excluded from baseline measurements if a qualitative argument indicates that they are negligible. For example, baseline woody debris stocks can be assumed to be zero on crop lands. CCAR explicitly requires considering terrestrial emissions from site preparation.

Table 26. Sinks, Sources, and Gases Included in Afforestation Methodology Project Boundary

Physical Boundary and Emissions Sources or Sinks Included	Gas	Climate Leaders	RGGI	CCX	CCAR	CDM
Live tree above-ground	**CO_2**	Y	Y	Y	Y	Y
Live tree below-ground	**CO_2**	Y	Y	Y (coarse roots)	Y	Y
Standing dead trees	**CO_2**	Y	Y (but conditional for baseline)	N	Y	Conditional
Shrubs	**CO_2**	Y	Optional	N	Y	Optional
Woody debris	**CO_2**	Y	Conditional	N	Y	Conditional
Forest floor	**CO_2**	Y	Optional	N	Y	Optional
Soil	**CO_2**	Y	Y	Y	Y	Conditional
Wood products	**CO_2**	N	N	N	Y	N
Management activities	**CO_2**	Y	N	N	On-site only	In biomass measurements
	CH_4	Y	N	N	On-site only	Y
	N_20	Y	N	N	On-site only	N

The Climate Leaders guidelines express support for including methane and nitrous oxide emissions but methodological guidance for making calculations is not provided, and emissions of these gases are not calculated by the RAPCOE tool provided for quantifying emissions reductions using the Climate Leaders methodology.

In the CCX program requires greater rigor in accounting for forest management projects than for afforestation projects. If an afforestation project eventually includes harvest, at the time of harvest it converts to a forest management project and is required to do rigorous carbon quantification. Also, CCX forest management accounting includes carbon in wood products and landfills.

The term “management activities” is sometimes used to refer to fuel used in machinery and sometimes used to address terrestrial emissions resulting from implementing project activities, such as burning for site preparation. In this regard, Climate Leaders focuses on emissions from fuel used in equipment. CCAR and CDM focus on terrestrial emissions, such as N_2O from nitrogen fertilizer application and methane estimated to occur as a result of burning of biomass. These terrestrial emissions are estimated using IPCC factors. Loss of biomass carbon stocks resulting from management activities is not tracked separately as it is reflected in measurements of biomass carbon stocks.

The term “leakage” is used to mean two different things. In U.S. programs, the term is typically used to refer to displacement of emissions from inside the project boundary to outside the project boundary, as a result of project activities. CDM uses the term more broadly, referring to both displacement and also referring to increases in fuel emissions resulting from use of equipment to carry out management activities. Leakage accounting for each protocol is summarized in Table 27.

Table 27. Leakage Provisions of Afforestation Methodologies

Protocol Parameter	Climate Leaders	RGGI	CCX	CCAR	CDM
Leakage	Count “activity shifting” which is shifting pre-project activities to locations outside the project boundary but within the same ownership	Not considered	Not considered	Decision tree assigns leakage deduction rates from 0 to 50%	Count: • displacement of pre-project grazing • increased use of wood posts for fencing • displacement of fuel-wood collection • increases in fuel emissions resulting from use of equipment to carry out management activities

5.4.1 Implications for Sample Projects

Differences in boundary definitions have a small affect on the sample projects because the differences all involve small sinks and sources. Implications of accounting boundaries are tied to baselines, quantification methods, and the magnitudes of each flux, and are presented in the section on quantification. Implications with respect to leakage are as follows:

Project #1: Because there is no harvest of wood products in either the baseline or the project, none of the protocols attribute leakage of woody biomass carbon to the project. The project does reduce grazing, and the CDM protocol requires consideration of leakage from displacement of grazing to other lands. The project was implemented during a time when beef prices were very low, the cattle formerly on project lands were beef cattle, and project proponents claimed that ranchers in the area were reducing cattle populations because they were losing money raising cattle. Thus, project proponents argued that the net reduction in herd size meant that the removal of cattle from project lands did not result in an increase in cattle elsewhere, and this did not cause emissions from an increase in overgrazing, use of fertilizer or fuel, or reduction in standing biomass on other lands. This argument was accepted for the purpose of leakage accounting, and the project was assigned zero leakage from grazing displacement. CCAR also considers grazing displacement and gives displacement percentages as a function of canopy cover on the project. The same logic of herd size reduction avoiding leakage was applied to the CCAR accounting.

Project #2: CCAR rules apply a 24% leakage discount to the SE afforestation project because crop production is displaced. 24% is a flat rate that applies to all project that convert crop land to forest. None of the other methodologies applied a leakage rate to the project.

5.5 Permanence

For forest carbon sequestration projects, the term “permanence” refers to the fact that the sequestration can be reversed, cancelling the GHG benefit achieved by a project. Permanence encompasses both the length of time a project is required to keep carbon stored and provisions for avoiding reversals or making the atmosphere whole in the case of a reversal. Separate subsections below address (a) the length of time a project is required to maintain carbon sequestration and (b) provisions to mitigate reversals of carbon sequestration.

Requirements for Keeping Carbon Stored

Providing the least temporal durability of obligations to maintain sequestration is the CCX protocol. Offset generators are contractually required only to maintain offsets through December 31, 2010. Also, CCX requires landowners to attest that they intend to maintain forests for at least 15 years, unless there is “catastrophic loss” or sale of the land. However, there are no apparent legal consequences of reversals after 2010.

The proposed new CCAR protocol assessed here requires that landowners maintain carbon stocks underlying offsets for 100 years from the date of such offsets are issued. In contrast, the current CCAR protocol requires a permanent conservation easement protecting carbon storage, in essence requiring the maintenance of carbon stocks in perpetuity.

RGGI requires that carbon sequestration be protected by a permanent conservation easement registered with the land title, similar to the current CCAR forestry protocol.

CDM protects against reversals by limiting the life of forest carbon offsets. Forestry offsets can last no longer than 60 years. Temporary credits are issued, and must be replaced with other compliance credits (allowances or other offsets) when the temporary offsets expire. As a part of a compliance system, CDM can be tracked and replacement can be enforced. Specifically, CDM can require periodic re-verification that the offset continues to exist, and if an offset is not re-verified, the registry can cancel the offset. Under buyer liability, the user of the offset could be required to replace it or face penalties for excess emissions. Under seller liability, a lien or other legal claim could be made on the assets of the offset originator, and if the offset seller does not replace the reversed offset the assets could be seized and sold to purchase replacement offsets. In theory, a voluntary offset program could also place a claim on originators of offsets, but this claim would have to be a permanent easement or similar real interest in the land for the claim to be permanent. It is not clear whether a voluntary program would have both the will and resources to prosecute claims for replacement of reversed offsets. One could argue that the CDM approach to permanence provides even more protection than the RGGI approach because the sequestration is automatically assumed to be reversed and if the offset was used to mitigate an emission, another allowance or newly-verified offset must be retired to mitigate that original emission at the end of the commitment period (for a temporary CER) or crediting period (for a long-term CER).

Addressing Reversals of Sequestration

Reversal of sequestration during the life of the project is handled differently in the different programs. Climate Leaders guidance is not explicit but implies that if periodic monitoring shows that underlying carbon has been lost, this reversal needs to be reported and addressed.

CCX provides that offsets are cancelled upon sale of the land where they are generated, unless the new owner re-enrolls the land in the CCX offset program. Upon creation of sequestration credits, 20% of those credits are placed in a buffer account. If there is catastrophic loss of forest carbon, reversed offsets will be replaced from the CCX buffer up to the amount of offsets in the buffer account. At the end of each market period (periods have been four years, with the current period expiring at the end of 2010) credits remaining in the buffer account are released to the entities that created the offsets. If more carbon is lost than is in the buffer account, offsets beyond the buffer amount will not be cancelled.[82] In other words, there is no compensation for such risk.

Under the revised draft CCAR protocol, verifiers rate the risk of reversal of each project; this risk rating determines the proportion of the project's created offsets that are placed in a buffer account. The CCAR risk rating system is complex, as is the operation of the buffer once in place. If the difference between the project's carbon stock and its modeled buffer stock decreases to less than the amount of released offsets, the shortfall is covered with offsets from the buffer account. The project first draws the credits it has placed in the buffer, and then draws on credits contributed by others. The proposed guidelines are silent on what occurs if and when no buffer credits remain.

RGGI rules require that 10% of the carbon sequestration that otherwise would count as offsets is not credited, to provide for potential reversals of sequestration. The project can avoid this debit, by maintaining an approved "long term" insurance to replace reversed offsets. This analysis did not comprehensively investigate the availability of insurance against offset reversal. Anecdotal evidence suggests that if such insurance can be obtained it will cost more than the current market value of the offsets. This cost is because the insurer will probably purchase and hold a number of emission allowances equal to the number of insured offsets, to avoid the risk that the insurer would have to acquire replacement offsets at a much higher price at some time far in the future.

[82] CCX Rulebook, 2006 revision, section 9.8.4.4.

General CDM and Kyoto accounting rules require cancellation of credits found to be invalid. The Kyoto Protocol is an agreement between nations and a nation is held responsible if reversal of sequestration invalidates credits held in one if its accounts.[83]

Guidelines tend to be vague about the consequences of reversals judged to be intentional, and rules for determining intentionality of reversals. It is not clear why a project developer who intentionally reverses sequestration would pay for verification of the carbon loss and report that loss to an offset program. Programs implicitly address intentional reversals by stating that if a project developer fails to submit required periodic verifications, the affected offsets are cancelled.

Table 28. Permanence Guidelines for Afforestation Projects

Protocol Parameter	Climate Leaders	RGGI	CCX	CCAR	CDM
Permanence	Acknowledged: Requirements not yet established; options for addressing reversal are listed in the offsets guidance document	Permanent conservation easement requiring land to remain forested required 10% of sequestration is not issued as credits to cover reversals If project sponsor retains long-term insurance of credits the 10% discount is waived	20% of emission reductions placed in Reserve Pool Reversals covered from reserve Withheld offsets are released to creator at end of market period (2010) Projects that do not remain enrolled surrender all credits accrued	Legal instrument committing to maintaining sequestration for 100 years Insurance for reversal either buffer pool administered through Reserve or approved insurance contact with third-party provider Buffer withholding proportion determined through risk assessment	Offsets are temporary and must be replaced on expiration If periodic measurements do not show maintenance of sequestration, offsets are cancelled

5.5.1 Implications for Sample Projects

With the exception of CCAR, permanence provisions have a modest effect on the number of offsets generated by the sample projects assessed here. The complex CCAR risk rating system considers many different types of risk, assigns a value to each, and estimates the proportion of the risk that is mitigated by the project. The cumulative risk discount is often greater for CCAR than for any other system. CCAR assesses 13 different variables, assigns a risk to each, and sums the risks. Some of these variables can have individual risks that earn a 40-90% risk discount, and it is possible for a project to have a cumulative risk rating greater than 100% (e.g. no tons of sequestration would count as offsets). Even apparently low risk projects can earn a significant risk rating for a single risk variable, resulting in a large risk discount for the project. For example, the Southeast afforestation project assessed here earned a 25% mitigated risk rating of conversion, resulting in a total risk rating of 36.25% for the project. In contrast, the PNW restoration project earned only a 7% risk deduction.

[83] The Kyoto Protocol Reference Manual on Accounting of Emissions and Assigned Amounts (UNFCCC Secretariat, 2007, page 66) states that a party must replace credits cancelled because of reversal of carbon storage, but the manual is silent regarding who might own or pay for the replacement credits.

RGGI's 10% risk discount is the next largest deduction. The CCX 20% buffer withholding appears large. However, because the withheld offsets are released at the end of every four-year market period, only 20% of the offsets created in the most recent 0-3 years are withheld, and thus the cumulative amount withheld will be relatively small. Climate Leaders and CDM are given no risk withholding in this analysis. However, CDM limits the life of forestry credits to no more than 60 years and at the expiration all the temporary credits would be cancelled and would have to be replaced. This looming loss of credits substantially reduces the value of CDM forestry credits in the marketplace.

5.6 Baseline Determination

The baseline is the carbon stock under pre-project business-as-usual management. CCX and RGGI use the carbon stock present at the time of project initiation as the baseline, and the crediting baseline does not change over time.

Climate Leaders uses the RAPCOE model to estimate the likely cumulative land use change over 15 years, and the implications for carbon stock. The model takes the observed land use changes for an area (typically an area is a few counties in size) and calculates the carbon stock change by multiplying the rate of land use change by the amount of carbon stock change resulting from each land use change, and summing for all possible land use changes. Although most land remains in its original use, in much of the U.S. there is a slight trend of crop and pasture land to convert to forest. For most locations, this general trend results in a modest baseline carbon stock increase, usually less than 3% and often less than 1% of the carbon stock increase resulting from afforestation.

CCAR requires modeling of changes in vegetation present prior to the project, under continuation of pre-project management regimes. This modeling is used to predict carbon stocks for 100 years. This modeling generally does not estimate effects of stochastic events such as fire, drought and insect pest irruptions. Modeling of management activities typically uses costs and prices observed at the time of modeling, possibly with a regular price adjustment over time. However, over the course of a few years, actual prices often vary tremendously both relative to earlier prices for the same product and relative to prices of other products. Vegetation growth models can be very accurate for relatively short periods, such as a decade. However, model predictions become much less accurate and many modelers regard them as little more than meaningless for projections longer than a few decades. For these reasons we do not recommend basing offset crediting on long-term computer simulations.

CDM additionality requirements are that the project carbon stocks would not recover in the absence of the project.

Table 29. Baseline Determination for Afforestation Protocols

Protocol Parameter	Climate Leaders	RGGI	CCX	CCAR	CDM
Baseline determination	Calculated by RAPCOE tool based on: Cumulative probability of land-use transition by county Multiplied by carbon sequestration consequence of each land-use change Duration of project, up to 20 years	Carbon stock present at project initiation, measured	Carbon stock present at project, initiation, which is often assumed to be zero	Computer simulation of change in vegetation carbon stocks in absence of project	Identification of plausible alternative land uses for project lands For project to be additional, either there is no woody vegetation present in the baseline use, or baseline degradation must be continuing, thus baseline carbon stocks are assumed to not increase over time

For many emission reduction projects, the baseline drives the calculated amounts of emission reductions. For sequestration projects such as afforestation projects, the situation is the opposite. Most methods assume that the baseline carbon stock is relatively constant, thus the emission benefit largely results from increase in carbon stocks due to the project (adjusted for leakage and risk discounts).

The methodology that is different from the rest is CCAR. CCAR seeks to detect business-as-usual sequestration by requiring modeling of tree growth under the baseline. Potentially, this modeling could show natural regeneration of trees on the site, resulting in none of the carbon stored by the project as additional to the crediting baseline.

The CCAR method is intended to detect non-additional tons, and avoid crediting those tons as offsets. For reasons stated above, this modeling approach is unreliable. However, it is not clear whether the modeling is more or less reliable than the approach of the other systems, which assume little or no baseline change in carbon stocks.

5.6.1 Baseline Rule Implications for Sample Projects

As noted above, the baseline determines what level of sequestration must be achieved before tons of sequestration start counting as offsets. If the methodology assumes that in the absence of the project the carbon stocks on project lands would remain constant, then the emission benefit of the project largely results from increases in carbon stocks (adjusted for leakage and risk discounts).

Four of the five methodologies assessed here assume that the baseline changes little over time. RGGI, CCAR, and CDM assume baseline carbon stocks remain constant over time. Climate Leaders assumes a small increase.

With the CCAR baseline methodology, the baseline could remain constant over time, or could change dramatically over time. For afforestation of crop land, if the baseline practice remains cropping, then the CCAR method gives the same result as the other methods: The baseline carbon stock remains constant over time.

The CCAR method can give a very different baseline if some trees are present on the project lands prior to the start of the project, or if trees would naturally regenerate on project lands in the absence of the project. A small rate of net growth of baseline trees would result in a significant increase in baseline carbon stocks, which would result in a significant amount of the carbon sequestered on project lands not counting as offsets.

The developer of the PNW restoration project analyzed here claimed that it is conservative to argue that the baseline carbon stock would remain constant over time. The project developer argued that the past several decades showed a clear trend of carbon loss. The project developer stated that the trend of carbon loss could be projected into the future, but that the project would assume that further degradation is stopped and that the carbon stock remains at the baseline amount. However, the history of carbon stock change on the project lands was not a simple trend of loss. The property appears to have had periods when the carbon stock was increasing. The CCAR methodology would reflect the changing carbon stocks resulting from changes in land management regulations, economics, and vegetation dynamics, as of the time when the baseline modeling is done.

One could argue that dense stocking of White Fir (with significant increase in carbon stock) present on the PNW project lands in 1990 would occur again in the future as a result of continuation of baseline management. The project proponent argues that learning from the previous high stocking and subsequent insect-caused mortality results in baseline management aggressively controlling White Fir density through timber harvest. For this analysis, we accepted the project proponent's qualitative argument that the baseline carbon stock is not expected to increase, because we had no objective facts refuting the claims. Thus, for this analysis we set model inputs and parameters to cause the modeled baseline carbon stock to remain constant over time. Specifically, emissions from harvest and decomposition following natural mortality of trees present at the start of the project (plus any in-growth that would have naturally occurred in the absence of the project) are adjusted by changing the assumed harvest rate to make the amount of emissions equal to sequestration in growth of remaining pre-existing trees and natural in-growth. The baseline is counter factual and plausible so there is no way to disprove it. But there is significant likelihood that over 100 years the carbon stock would have increased or decreased in the absence of the project.

The Southeast afforestation project converted land from crop use. The Climate Leaders use of historical baseline conversion rates give an objective measure of average behavior in the past. This gives an accurate projection of future trends if past conditions continue. If crops become more valuable relative to forests, the Climate Leaders approach would overstate baseline sequestration. If wood products become more valuable relative to crops and development, the historical benchmark could understate afforestation.

5.7 Quantification and Monitoring of Offset Credits

For some project types, monitoring is relatively distinct from quantification of project outcomes. For afforestation projects, the measurements used to calculate project outcomes are the most reliable quantitative monitoring of the project. Monitoring requirements under each protocol are presented in Table 30. All protocols except for CCX require some level of field measurement, except CCX, which allows the use of tables without field data, if there is no harvesting or if the project is very small.

Some methodologies require monitoring of project conditions between times when measurements occur. After the first few years when planting survival is being measured, field measurements of trees for carbon stock calculations are typically only scheduled to occur once every 5-10 years. Offset programs may require monitoring to provide annual qualitative checks that the project is proceeding roughly according to plan, or may require annual attestation by the project developer that the project remains in control of project lands and that trees continue to grow with minimal effects of disturbance.

CCX allows afforestation projects that do not include any harvesting to calculate credits using published tables. However, projects that include harvesting come under forest management project accounting rules and measurements are required.

Some offset programs refer to the annual verification of offsets. This research revealed no afforestation projects that have been issued serialized offsets and it is not clear how annual verifications will be conducted if there is no data or calculation to verify. Avoided deforestation projects have been issued credits annually, without annual measurements of carbon stocks, and treatment of avoided deforestation projects might indicate how afforestation projects will be treated. CCAR, CCX and CDM methodologies all discuss calculation and attribution of annual sequestration amounts. The RGGI protocol discusses reporting periods. The Climate Leaders protocol does not mention annual calculation, reporting, or attestation of sequestration. If sequestration is modeled annually, this modeling could be verified but that verification should be one time for the entire period modeled between field measurements. Also, verification is expensive, and we expect projects to resist paying for verification annually if there are no new data or calculations to verify. This analysis did not road test annual monitoring provisions of the tested methodologies.

Table 30. Monitoring Guidelines for Afforestation Protocols

Protocol Parameter	Climate Leaders	RGGI	CCX	CCAR	CDM
Monitoring	Required	Required	Required	Required	Required
	More thorough guidance is planned. Modeling approach: Model application with periodic validation with field data sensitivity analysis Direct field measurement approach: Field sampling based on variability of carbon stocks and desired precision	At a minimum every 5 years the following is required: Direct measurement that demonstrate combined carbon pool measurement that there is 95% confidence that the reported value is within 10% of true mean Minimum sampling plots as set by equation in (3)(b) Measurement procedures consistent with guidance in U.S. Dept. of Energy 1605(b)	Annual desk review and audit Annual attestation that the project and aggregator are conforming to CCX rules	Assessed on annual basis: Carbon stock estimate: field sampling and modeled growth Inventory Confidence Harvested wood product volumes Risk Assessment Reserve Calculation Account of disturbances Leakage	Permanent sample plots to monitor carbon stock changes in living tree biomass Methodology determines sampling needs with precision level +-10% of mean at 95% confidence interval

5.7.1 Implications for Sample Projects

The methodologies allow use of very different methods for quantifying on-site sequestration. Choices of different methods, equations, and factors could have a significant effect on the calculated amounts of sequestration.[84] However, to make this analysis highlight differences resulting from other components of methodologies, this analysis used similar carbon quantification methods for all methodologies.

The CCAR deduction for statistical uncertainty in estimates from sampling reduced the amount of creditable sequestration relative to other methodologies.

All methodologies explicitly or implicitly require some measurements of the diameters and/or heights of live trees larger than sapling size.[85] Other measurements are stated as necessary, but may be avoided if the project developer can make a convincing argument that the carbon pool is not decreasing and the project developer is willing to forgo credits based on sequestration in the unmeasured carbon pools, as discussed above in the section on accounting boundaries. Methods for obtaining particular values are given in Table 31. Values are obtained from a variety of methods, including field sample measurements, modeling, GIS mapping, default factors, and calculation using a combination of measurements, equations and/or factors. The accounting systems reviewed here allow two different ways of calculating live tree carbon stocks from tree measurements. One approach is called the "biomass expansion factor" (BEF) approach. The other approach is the "allometric" approach. The CDM methodology explicitly provides for use of BEFs. The CCAR protocol appears to exclude BEFs because it discusses use of individual tree allometric equations. RGGI, Climate Leaders, and CCX are silent on the issue.

The BEF approach uses the mean diameter of measured trees or the calculated volume of wood per hectare as a starting point, and uses an equation or factor to estimate total biomass from the starting input value. This approach only gives accurate results if the project stands have the same species and variation in tree sizes as the stand used to develop the BEF. However, the BEF approach is typically used in places where little local data is available. Our experience on other projects has found the BEF approach to be unreliable because project stands are not like the stands where the BEF was developed, and this inaccuracy is greater in stands with more variation in tree sizes. Based on this experience, we do not expect that the BEF approach would give reliable results for the sample projects (especially the PNW restoration project that has significant variation in tree sizes).

The allometric approach was used to calculate carbon stocks for this analysis. The allometric approach uses tree species, diameter and height to calculate the biomass of each tree. Then the tree measurements are scaled up to a per-hectare basis. If tree heights are used in addition to diameter, and wood density as accounted for, this approach yields accurate results in a wide range of circumstances, including situations substantially different from the situations where tree biomass equations were developed.

[84] Use of biomass expansion factors instead of individual-tree allometric equations can yield significantly different calculated carbon stocks, especially if tree diameters are heterogeneous, especially if the average stand diameter is interpreted to be the arithmetic mean diameter instead of the quadratic mean diameter. Requirements for statistical precision mean that substantial differences in measured biomass carbon stocks should be unlikely, but they could occur. Use of different allometric equations could cause estimates to differ by 10-30%. In the absence of a plot design that controls for spatial variability of soil carbon, many measurement methods would fail to detect changes in soil carbon stocks.

[85] For the CCX program, projects could eventually move from being classified as afforestation projects that use a table to estimate sequestration to being classified as forest management projects that are required to measure tree growth

The scope of this project was not sufficient to cover calculation of carbon stocks using multiple methods. Additional research would be useful to quantify the difference in carbon stocks calculated using standard BEF values and the allometric approach.

This analysis assumed that project developers would limit their costs and risks through their choices of how to implement accounting guidance. Specifically, all carbon pools that are expected to produce a small amount of offsets with a value less than the cost of measurement were excluded from measurement if the exclusion is allowed. Also, if *ex ante* projection or modeling of sequestration is allowed instead of measuring actual outcomes *ex post*, the *ex ante* or modeling approach was used.

Quantification of sinks and sources for both sample projects are provided. Values across all methodologies for project #1, the PNW forest restoration project, are presented in Table 32. For project #2, the SE afforestation project, they are presented in Table 33.

Table 31. Afforestation Value Sources in This Analysis[86]

	Climate Leaders	RGGI	CCX	CCAR	CDM
BASELINE					
Area (acres)	GIS, survey	GIS, survey	GIS, survey	GIS, survey	GIS, survey
Live trees, aboveground	Modeled	Sample	Sample	Sample	Sample
Live trees, belowground	Modeled	Equation	Equation	Equation	Equation or factor
Standing dead trees	Modeled	Sample	Not included	Sample	Sample
Shrubs	Modeled	Not included	Not included	Sample	Various
Woody debris	Sample	Sample	Not included	Sample	Sample
Forest floor	Sample	Not included	Not included	Sample	Not included
Soil	Sample	Sample	Sample	Sample	Not included
Wood products	Not included	Not included	Not included	Not included	Not included
Fire methane	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Fuel	Estimated	Estimated	Estimated	Estimated	Estimated
PROJECT					
Live trees, aboveground	Sample	Sample	Sample	Sample	Sample
Live trees, belowground	Modeled	Equation	Equation	Equation	Equation or factor
Standing dead trees	Sample	Sample	Not included	Sample	Sample
Shrubs	Modeled	Not included	Not included	Sample	Not included
Woody debris	Sample	Sample	Not included	Sample	Sample
Forest floor	Sample	Not included	Not included	Sample	Not included
Soil	Sample	Sample	Sample	Sample	Not included
Wood products	Not included	Not included	Equations	Equations	Not included
Fire methane	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Fuel	Estimated	Estimated	Estimated	Estimated	Estimated
Leakage	Modeled	Not included	Not included	Decision tree	Equations

[86] Some programs specify that measurement of a pool is to be done except in specified situations where the project developer may choose to exclude the pool. Some programs specify some pools as optional. This table summarizes data sources used in this analysis. Thus, pools that are not considered in this analysis are listed as "not Included", which may mean that the pool is prohibited from being counted, or the conditions of the projects are such that the pool can be excluded, or that it is optional to include the pool and a rational developer would exclude the pool because it costs more to measure than is justified by the sequestration that would be detected by measuring the project.

Table 32. Quantification of Afforestation Project #1 - PNW (All figures in tCO_2e)

	Climate Leaders	RGGI[87]	CCX	CCAR	CDM
Baseline Carbon Stocks (A)	**17,684**	**16,956**	**16,956**	**19,056**	**2,100**
Live trees, ABGR	466	0	0	0	0
Live trees, Belowground	101	0	0	0	0
Standing dead trees	50			0	0
Shrubs	43		0	2,100	2,100
Woody Debris	39			0	0
Forest Floor	29			0	
Soil	16,956	16,956	16,956	16,956	0
Wood Products					
Fire methane					
Fuel	*0*	*0*	*0*	*0*	*0*
Project Carbon Stocks (B)	**42,947**	**40,738**	**37,984**	**42,947**	**20,258**
Live trees, ABGR	14,388	14,388	14,388	14,388	14,388
Live trees, Belowground	3,118	3,118	3,118	3,118	3,118
Standing dead trees	1,542	1542		1,542	1,542
Shrubs	1,320			1,320	0
Woody Debris	1,212	1,212		1,212	1,212
Forest Floor	891			891	
Soil	20,478	20,478	20,478	20,478	
Wood Products			0	0	
Fire methane					
Fuel	*-2*	*0*	*0*	*-2*	*-2*
Leakage (C)				**0**	**0**
Buffers and Discounts (D)		**2,378**	**317**	**5,017**	
Total offsets (B-(A+C+D))	**25,263**	**21,404**	**20,711**	**18,874**	**18,158**

Note: Blank entries indicate factor/pool not included in protocol; zero indicates factor/pool is included and value is <0.5 tCO2e or not calculated due to lack of data.

[87] All emissions reductions under the RGGI protocol are presented in short tons CO2e, but have been converted to metric tons for the purpose of comparison across protocols.

Table 33. Quantification of Afforestation Project #2 – SE (All figures in tCO_2e)

	Climate Leaders	RGGI[88]	CCX	CCAR	CDM
Baseline Carbon Stocks (A)	**3,307**	**3,266**	**3,266**	**3,266**	**0**
Live trees, ABGR	19	0	0	0	0
Live trees, Belowground	4	0	0	0	0
Standing dead trees	1			0	0
Shrubs	4			0	0
Woody Debris	4			0	0
Forest Floor	8			0	
Soil	3,266	3,266	3,266	3,266	0
Wood Products					
Fire methane					
Fuel	*0*	*0*	*0*	*0*	*0*
Project Carbon Stocks (B)	**4,634**	**4,269**	**4,534**	**4,662**	**881**
Live trees, ABGR	594	594	594	594	594
Live trees, Belowground	129	129	129	129	129
Standing dead trees	29	29		29	29
Shrubs	110			110	0
Woody Debris	131	131		131	131
Forest Floor	257			257	
Soil	3,386	3,386	3,386	3,386	
Wood Products			424	424	
Fire methane					
Fuel	*-2*	*0*	*0*	*-2*	*-2*
Leakage (C)				**430**	
Buffers and Discounts (D)		**100**	**15**	**644**	
Total offsets (B-(A+C+D))	**1,328**	**903**	**1,253**	**719**	**881**

Note: Blank entries indicate factor/pool not included in protocol; zero indicates factor/pool is included and value is <0.5 tCO2e or not calculated due to lack of data.

Appropriately, the fundamental driver of the amount of offsets attributed to both projects under all five methodologies is growth of live trees. However, in specific instances, several other items had substantial effects on the number of offsets credited.

- Permanence: Other than tree growth, the biggest single effect on the number of offsets credited to a project was a risk discount in the CCAR methodology. CCAR uses assessment of 13 variables to construct a quantitative risk of reversal of sequestration. This risk is then used to determine what proportion of the net sequestration is held back as an insurance buffer to cover possible future reversal of sequestration. For the SE afforestation project, a single risk variable—the risk that the land would be developed at some time in the future—increased the project's risk rating. The combined risk discount resulted in 36.25% of the net sequestration not counting as offsets. The PNW project there was only a 7% risk discount.

[88] All emissions reductions under the RGGI protocol are presented in short tons CO2e, but have been converted to metric tons for the purpose of comparison across protocols.

- Leakage: For the sample projects, leakage provisions have a large effect on the difference in the number of credits calculated under the different protocols, with CCAR giving a substantial deduction for the PNW project relative to other methodologies.
- Uncertainty and accuracy:
    - The CCAR methodology reduces the amount of sequestration calculated as creditable as a function of the statistical uncertainty resulting from sampling. When forests are variable, the sampling uncertainty will be higher, and CCAR will assign a greater deduction in the number of tons of sequestration that are creditable as offsets. CCAR is the only program to make this deduction.
    - RGGI requires that each carbon pool be measured with sufficient accuracy that the 95% confidence interval is no greater than 10% of the estimated mean carbon stock of that pool. Achieving this level of measurement precision requires significant sampling effort for pools that are highly variable, such as the shrub carbon pool. The rule does not allocate more sampling effort to large pools or pools that have large changes. As a result, the rule makes sampling inefficient and more expensive than is necessary to achieve accurate measurement of the net carbon sequestration of a project[89].
- Baseline determination:
    - In theory, the modeling of changes in baseline carbon stocks over time required by CCAR could have a huge effect on the amount of creditable sequestration. However, we expect that all project developers will adjust model inputs and factors to have the model predictions have little effect on the baseline.
    - In practice, a more reliable approach would be to select benchmark sites not controlled by the project and track carbon stock changes on those lands. The drawback of this "control group" approach is that the baseline cannot be determined in advance, and the project developer takes the risk that much of the carbon they store will not count as offsets. This approach had been considered by at least one system in the past, and was dropped because of project developer antipathy.
    - Climate Leaders applies a baseline rate of afforestation based on the observed rate of afforestation in the county over the most recent 15 years for which data is available. As a result, the Climate Leaders baseline counts carbon in trees and other biomass pools that were not present at the time the project started, but are assumed to grow in the absence of the project. Baseline numbers under other methods reflect carbon stocks present at the time of project initiation. Thus the Climate Leaders counts show baseline carbon stocks that are not present under the other systems.
- Transaction costs: Although transaction costs are not estimated as a part of this analysis, they are worth consideration. High transaction costs will result in developers and landowners not doing projects, resulting in few offsets or no offsets being produced. The RGGI requirement that each carbon pool separately be measured with no more than 10% uncertainty with 95%

[89] Some of the measurements used in this analysis did not meet the RGGI statistical precision requirement. Technically, this failure should have resulted in the project accounting being rejected, and the project receiving no RGGI credits. However, to illustrate other differences between the methodologies, for this analysis, this violation of the sampling precision requirement was ignored, and offsets calculated as if the sampling precision requirement had been met.

statistical confidence makes RGGI sampling more expensive than sampling required by other programs. CCAR is requiring that all verification personnel be individually certified by ANSI, which significantly increases verifier costs. As a result, some verifiers are letting their credentials lapse and remaining verifiers will be very expensive. Requiring annual verification will increase transaction costs for smaller projects that otherwise would not verify and claim credits annually.

5.8 Pre-Project Emission Reduction Estimates

Protocol requirements for pre-project emission reduction estimates, as well as quantification tools available, are presented in Table 34. Estimates of the amount of emission reductions a project is expected to produce have no effect on the actual number of offsets produced, unless offset generation is based on modeling or tables instead of observation of project outcomes.

Table 34. Pre-project emission reduction estimates and calculation tools for Afforestation Protocols

Protocol Parameter	Climate Leaders	RGGI	CCX	CCAR	CDM
Estimate Pre-Project Emissions	Optional; use of FORCARB2 model recommended	Baseline determination required not project carbon sequestration	Tables supplied; accepted models are listed; may apply for permission to use other models	Accepted models are listed; may apply for permission to use other models Measurements used for modeling can be no more than 12 years old	Required Choose own model or use yield tables
Software tool, model, or equations provided?	RAPCOE tool or alternative tools can be proposed by project developer	Equations	CCX Carbon Accumulation Tables	Equations	Equations; refer to National Inventories and IPCC guides for equation coefficients

5.9 Conclusions

Based on our review of afforestation/reforestation protocols across various programs and on road-testing with sample projects, we have the following conclusions and recommendations for protocol development:

- Accumulation of biomass in trees provides the largest on-site GHG benefit of afforestation projects and thus protocols should focus on getting accurate quantification of tree biomass stock changes. At this time, ground-based measurements of tree frequency, species, height, and diameter used as inputs to individual -tree allometric equations provide the most reliable quantification. In the future, remote sensing methods such as LIDAR may give equal or more accurate quantification.
- Several carbon pools and fluxes, including the forest floor, shrub, and soil, are frequently trivial in afforestation projects. We recommend having tests for the significance of all carbon pools and fluxes other than live trees, and rules for when pools and fluxes may be ignored.
- We recommend excluding wood product carbon from afforestation project offset accounting because wood product harvest is business-as-usual. 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.

- We do not recommend inclusion of methane emissions in afforestation project accounting. If methane emissions from burning are included, we recommend that field sampling be conducted to develop new factors for estimating methane emissions from burning.
- Permanence of forest emission offsets is a very important issue. For voluntary offset programs where little enforcement of old offset agreements can be expected, requiring permanent conservation easements or granting of land to conservation agencies is the most effective method of providing permanent atmospheric benefit. For compliance programs, serial numbers of affected offsets can be cancelled if a project developer ceases to provide periodic verification that sequestration continues. Although project developers can be held liable for replacing reversed offsets, these claims are likely not to be very enforceable unless the claims are recorded with the land deed. Alternatively, offsets can be considered permanent if the land is conveyed to a conservation agency and a fraction of achieved sequestration is withheld to cover reversals. If forest offsets are to be used for compliance, we recommend that either (a) periodic assessment of continued carbon storage be required and landowners be liable for replacing reversed offsets, or (b) land be owned by a conservation entity and a fraction of the sequestered carbon be held in reserved to cover emissions from disturbances such as fire.
- Leakage can make a large difference in the actual atmospheric benefit resulting from a project. There is uncertainty about the actual extent of leakage from afforestation projects and this is an area of ongoing research. Leakage is significantly affected by several factors that are difficult for offset methodologies to capture including global economic pressures. There are significant concerns with either assuming zero leakage for afforestation projects or with the use of substantial leakage rates based on econometric analyses. We recommend further research on how to address leakage for afforestation projects.[90] It may be that GHG emissions from leakage from afforestation projects are small.

[90] In practice, we believe that there is little current clearing of forest for crop or pasture use in the U.S. We suspect that the RAPCOE estimates are artifacts of clearing that was occurring in the 1980s, in the period used as input data for RAPCOE.