Livestock Project Reporting Protocol

Capturing and combusting methane from manure management systems

Version 1.0
June, 2007

The Climate Action Reserve

Livestock Management Project Reporting Protocol

Capturing and combusting methane from manure management systems

TABLE OF CONTENTS

I. Introduction

The Climate Action Reserve's (Reserve) Livestock Management Greenhouse Gas Project Reporting Protocol – for capturing and combusting biogas in a manure management system – provides guidance to account for and report greenhouse gas (GHG) emissions reductions associated with installing a manure biogas control system for livestock operations, such as dairy cattle and swine farms. The protocol focuses on quantifying the change in methane emissions, but also accounts for effects on carbon dioxide.

Established by the California Legislature in 2000 as a non-profit, public/private partnership, the California Climate Action Registry (California Registry) runs a voluntary GHG registry. Its purpose is to promote and facilitate the measurement, monitoring and reduction of GHG emissions. Participants in the program account for and verify their GHG emissions according to the Reserve's protocols.

Project developers that install manure biogas capture and combustion technologies use this document to register GHG reductions with the Reserve. It provides eligibility rules, methods to calculate reductions, performance-monitoring instructions, and procedures for reporting project information to the Reserve. Additionally, all project reports receive annual, independent verification by California Air Resources Board- and Reserve-approved verifiers. Guidance for verifiers to verify reductions is provided in the corresponding Manure Management Project Verification Protocol.

This project protocol facilitates the creation of GHG emissions reductions determined in a complete, consistent, transparent, accurate, and conservative manner, while incorporating relevant sources.[1]

Document organization

The Reserve's manure management project protocol has the following sections:

- The GHG Reduction Project
- Project Eligibility
- The Project Boundary
- GHG Reductions Calculation Methods
- Project Monitoring
- Reporting Parameters

Regarding associated environmental impacts related to installing a biogas control system, such as air and water quality issues, the Reserve discusses these potential concerns in Appendix A. Project developers that follow the guidance in this protocol and register GHG reductions with the Reserve must comply with all local, state, and national air and water quality regulations.

[1] See the WRI/WBCSD GHG Protocol for Project Accounting (Part I, Chapter 4) for a description of GHG accounting principles.

Recommendations for taking an entity-level GHG emissions inventory are provided in Appendix D, which augment the guidance in the California Registry's General Reporting Protocol (GRP). To register GHG reductions with the Reserve, project developers are not required to take an annual entity-level GHG inventory of their livestock operation.

II. The GHG Reduction Project

Manure treated and stored under anaerobic conditions decomposes to produce methane, which, if uncontrolled, is emitted to the atmosphere. This predominantly occurs when livestock operations manage waste with liquid-based systems (e.g., in lagoons, ponds, tanks, or pits). Within the livestock sector, the primary drivers of methane generation include the amount of manure produced and the fraction of volatile solids that decompose anaerobically. Temperature and the retention time of manure during treatment and storage also affect its production. A biogas control system captures and combusts methane gas created as a result of manure management.

Project definition

For the purpose of this protocol, the GHG reduction project is the installation of a biogas control system[2] that captures and combusts methane gas from manure treatment and/or storage facilities on livestock operations and that commences operation on or after January 1, 2001. Captured biogas could be combusted on-site, or transported for off-site use (e.g., through gas distribution or transmission pipeline), or used to power vehicles. Regardless of how project developers take advantage of the captured biogas, the ultimate fate of the methane must be combustion. "Centralized digesters" that integrate waste from more than one livestock operation also meet this definition of the GHG reduction project.[3]

The biogas control system destroys methane associated with the management of livestock waste that would have otherwise been generated through uncontrolled, anaerobic manure treatment and/or storage and emitted to the atmosphere.

In addition to reducing methane, the installation of a biogas control system could impact carbon dioxide and nitrous oxide emissions associated with manure collection, transport, storage, treatment, and disposal. The effect could either increase or decrease these GHG emissions, depending on the project's particular circumstance. These system-related effects are secondary to the primary effect of the project (reducing methane emissions). Section IV, The Project Boundary, delineates the scope of the accounting framework.

---

[2] Biogas control systems are commonly called digesters, which may be designed and operated in a variety of ways, from ambient temperature covered lagoons to heated lagoons to mesophilic plug flow or complete mix concrete tank digesters.

[3] The protocol also does not preclude project developers from co-digesting organic matter in the biogas control system. However, the additional organics could impact the nutrient properties of digester effluent, which project developers should consider when assessing the project's associated water quality impacts.

The project developer

Project developers could be livestock owners and operators, such as dairy cattle, beef cattle, or swine farmers. However, they could also include other entities, such as third-party aggregators. Ownership of the GHG reductions should be established by clear and explicit title.

Additional manure management GHG reduction activities

The Reserve recognizes that project developers could implement a variety of GHG reduction activities at a livestock operation, which are complex interrelated systems that make use of several types and combinations of manure management practices. Installing technology to capture and combust methane from waste storage and/or treatment systems is but one of many projects that could occur at a livestock operation. Several options to modify solid and/or liquid manure management practices that do not involve a biogas control system – i.e., a digester – could also reduce methane, carbon dioxide, and nitrous emissions (including land application). And a project developer could also change dietary regimes to reduce methane (either enteric fermentation or waste management-related) and nitrous oxide.

However, at this time, GHG reduction activities not associated with installing a biogas control system do not meet this protocol's definition of the GHG reduction project. Furthermore, producing power for the electricity grid (and thus displacing fossil-fueled power plant GHG emissions) is a complementary and separate GHG project activity to destroying methane gas from waste treatment/storage, and not included within this protocol's accounting framework.

The Reserve anticipates augmenting this document to incorporate GHG reductions associated with manure management and livestock operations beyond methane destruction from biogas control systems. Indeed, the project boundary and GHG reduction calculation approach are designed to support such amendments. And, more broadly, new protocols may also be added in the future to facilitate reduction opportunities in the agriculture sector (as well as other sectors).

III. Eligibility Rules

Project developers using this protocol satisfy the following eligibility rules to register reductions with the Reserve. The criteria only apply to projects that meet the definition of a GHG reduction project.

Eligibility Rule I:	Additionality	→	*Meet performance standard*
		→	*Exceed regulatory requirements*
Eligibility Rule II:	Location	→	*U.S. farms*
Eligibility Rule III:	Project Start Date	→	*January 1, 2001*

Additionality

The Reserve strives to support only projects that yield surplus GHG reductions, which are additional to what might otherwise have occurred. That is, the reductions are above and beyond business-as-usual – the baseline case.

Project developers satisfy the "additionality" eligibility rule by passing two tests:

1. The Performance Standard Test, and
2. The Regulatory Test.

The Performance Standard Test. Project developers pass the Performance Standard Test by meeting a program-wide performance threshold – i.e., a standard of performance applicable to all manure management projects, established on an ex-ante basis. The performance threshold represents "better than business-as-usual." If the project meets the threshold, then it exceeds what would happen under the business-as-usual scenario and generates surplus/additional GHG reductions.

For this protocol, the Reserve uses a technology-specific threshold; sometimes also referred to as a practice-based threshold, where it serves as "best-practice standard" for managing livestock manure. By installing a biogas control system a project developer passes the Performance Standard Test.

The Reserve defined this Performance Standard by evaluating manure management practices in California and the U.S. A summary of the study to establish the threshold is provided in Appendix C.

The Reserve will periodically re-evaluate the appropriateness of the Performance Standard. All projects that pass this test are eligible to register reductions with the Reserve for the lifetime of the project-crediting period, even if the Performance Standard Test changes during mid-period. As stated in Section VII, Reporting Parameters, the project-crediting period is ten years.

The Regulatory Test. The Reserve's analysis of manure management practices in the U.S. identified no regulations that obligate livestock owners to invest in a manure biogas control system. The analysis looked most closely at recent, stringent California air quality regulations (e.g., SJVAPCD Rule 4570 and Sacrament AQMD Rule 496), and found that installing an anaerobic digester is one of several compliance options.

Although the Reserve found no regulations driving livestock operators to install a biogas control system, project developers pass the Regulatory Test by demonstrating that the preliminary determination from the analysis of manure management practices in the U.S. continues to hold true for their region. That is, project developers show that there are no state or federal regulations (as well as local agency ordinances/rulings) requiring the installation of a biogas control system. All projects that pass this test are eligible to register reductions with the Reserve for the lifetime of the project-crediting period (ten years), even if a regulatory agency with authority over a livestock operation passes a rule obligating the installation of a biogas control system during mid-period.

Additionally, project developers pass the Reserve's Regulatory Test by demonstrating that the project meets local air and water quality regulations. Projects that do not comply with air and water quality regulations are not eligible to register GHG reductions with the Reserve.

Location

All projects located at livestock operations in the U.S. are eligible to register reductions with the Reserve. The scope of the analysis of manure management practices that formed the basis of the Performance Standard covered livestock operations in CA and the U.S. Therefore, the Reserve will treat GHG reductions from all U.S.-based projects that follow the guidance in this protocol equally.

The Reserve anticipates that this protocol could be applicable internationally. The calculation procedure is consistent with international practices and, considering its rigor, the Performance Standard could apply to regions outside of the U.S. However, at this time, reductions from international projects are not eligible to be registered with the Reserve.

Project start date

California Senate Bill 1771 (Sher) created the California Registry in September of 2000 to serve as a platform to record and register GHG reduction activities, among other things. This sent a signal to GHG-emitting entities, including farmers, that project activities could receive recognition for their carbon value. The establishment of the California Registry to support GHG reduction activities is the basis for the project start date criterion.

All GHG reduction projects that install a biogas control system are eligible to register reductions with the Reserve if the system started operating on or after January 1, 2001. Projects that began operating before January 1, 2001 are not eligible to register reductions according to this protocol. For the Reserve's purpose, the commencement of operation means a constructed system that is capturing and combusting methane gas from the treatment and/or storage of the project developer's livestock waste.

Projects that start operating between January 1, 2001 and January 1, 2008 may choose to begin their 10-year crediting period in the actual project start year or in 2008. Projects that are up and running after January 1, 2008 use the year their biogas control system start operating as the first year of their 10-year crediting period.

IV. The Project Boundary

The project boundary delineates the GHG sources and gasses assessed by project developers to determine the net change in emissions associated with installing a biogas control system. This protocol's project boundary captures sources from waste production to disposal, including off-site manure disposal. However, the calculation procedure only incorporates methane and carbon dioxide, so while nitrous oxide sources are technically within the boundary they are not assessed in the calculation procedure.

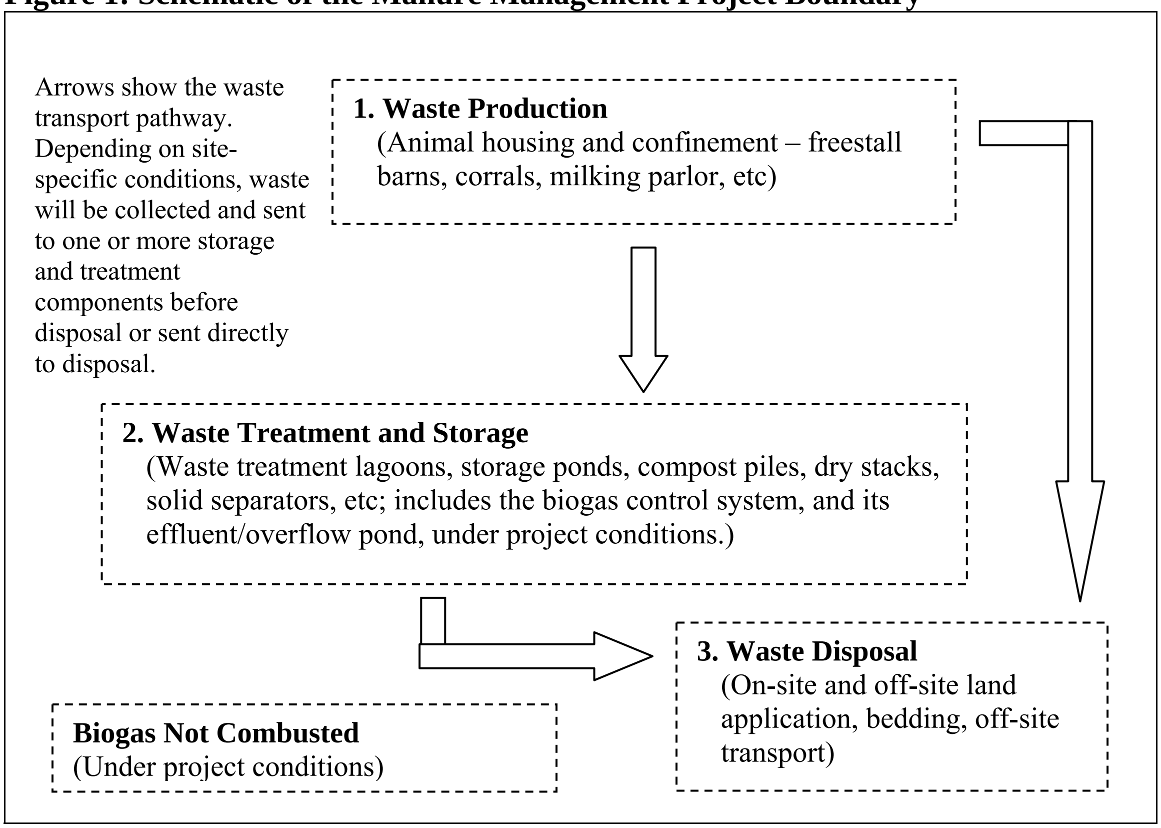
GHG source categories for manure management systems

A farm's manure management system is dictated by site-specific conditions. The design and physical layout of a particular operation will influence its make-up of GHG sources and types of gasses. However, regardless of a livestock operation's individual characteristics, modifying its manure management system (e.g., installing a biogas control system) can increase or decrease GHG emissions from sources grouped under three broad source categories:

- Waste production,
- Waste treatment and storage,
- Waste disposal.

Figure 1 provides a general illustration that the project boundary; it encompasses the full manure management system (and includes GHG emissions from biogas control system). Table 1 (on page 9) identifies the main GHG source associated with the source categories and specifies the gasses included in the calculation procedure.

Figure 1: Schematic of the Manure Management Project Boundary



For the most part, the installation of a biogas control system will not alter emissions from the waste production area; however, in some cases, carbon dioxide emissions could change from the support equipment. The project will primarily result in a change of methane emissions from the waste treatment and storage area. Sources of emissions in the waste collection and transport and waste disposal areas could also be affected by the project.

Methane and carbon dioxide

At this time, only two gasses within the project boundary are quantified to assess the project's impact:

- Methane
- Carbon dioxide (could be excluded, as described below)

Methane. In most cases, the primary impact of installing a biogas control system corresponds with reductions of methane emissions associated with anaerobic decomposition of manure in the waste treatment and storage category.[4] The GHG reduction calculation procedure focuses on methane, as it will likely constitute the bulk of a project's reductions.

Carbon dioxide. In addition to methane, this protocol accounts for changes in direct carbon dioxide emissions from mobile and stationary combustion sources within the project boundary, which can either increase or decrease depending on project and farm specifics.[5] For example, methane gas captured in a biogas control system could be used in place of fossil fuels to power *on-site* stationary combustion devices, such as generators or pumping systems, or the project could alter the need to transport manure waste for off-site disposal.

Carbon dioxide emissions from biogas control systems are considered biogenic emissions (as opposed to anthropogenic) and will not be included in the GHG reduction calculation – per the Intergovernmental Panel on Climate Change's (IPCC) guidelines for captured landfill gas.[6]

Sources of carbon dioxide within the manure management system might not change as a result of the project, or could be insignificant. Therefore, project developers may conduct an assessment of the change in direct anthropogenic carbon dioxide emissions due to the project to determine if baseline and project carbon dioxide emissions need to be calculated on an annual basis. Project developers are only required to conduct an annual estimation of carbon dioxide emissions if project emissions exceed 5% of baseline. This is similar to the California Registry's policy for determining *de minimis* emissions for entity-wide GHG inventories.[7]

The protocol does not account for carbon dioxide reductions associated with displacing grid-delivered electricity. This is classified as an indirect emissions reduction activity

[4] Generally, the secondary impacts of a project correspond with supplemental GHG effects to the main reduction activity. They could have a minor or major effect on the project's reductions (either in a positive or negative direction) and in some cases they are unintentional. See also the WBCSD/WRI "GHG Protocol for Project Accounting" for a discussion of primary and secondary GHG effects.

[5] At this time, methane and nitrous oxide emissions from mobile and stationary combustion sources are not calculated.

[6] *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*; p.5.10, ftnt 4. The rationale is that carbon dioxide emitted during combustion represents the carbon dioxide that would have been emitted during natural decomposition of the manure. Emissions from the biogas control system do not yield a net increase in atmospheric carbon dioxide because they are theoretically equivalent to the carbon dioxide absorbed during plant/feed growth.

[7] See the Registry's General Report Protocol, Chapter 5

because the change in GHGs occurs from sources owned and controlled by the power producer, even though the project developer produces the renewable electricity that displaces the fossil-based electricity. Capturing and using methane to produce electricity for the grid would be defined as a complimentary and separate GHG reduction project.

In a separate development process, the Reserve would establish a project protocol for all grid-delivered renewable energy projects, applicable to indirect emissions reductions from using biogas from biogas control systems.

Box 1: The Reserve's treatment of nitrous oxide emissions

This protocol's project boundary conceptually encompasses sources of nitrous oxide emissions in the waste production, waste treatment and storage, and waste disposal source categories. However, project developers do not calculate nitrous oxide impacts. This determination is made for the sake of "conservativeness" since the high levels of uncertainty associated with the methods to assess nitrous oxide production could lead to overestimations of project reductions.

Procedures to calculate nitrous oxide emissions associated with a livestock operation's manure management system and from the application of manure to soils (both direct and indirect) rely on emission factors with at least an uncertainty range of a factor of two – either 100% above or 50% below the default value.[8] The reason for the large uncertainty is the complex emissions pathway from organic nitrogen in livestock waste to nitrous oxide – the nitrification-denitrification cycle.[9]

As the state-of-science advances and methods to calculate nitrous oxide emissions at the farm-level improve the Reserve will incorporate them into this protocol. In fact, as the project boundary includes sources from waste production to disposal it is set-up to integrate nitrous oxide calculations. The Reserve will work with project developers and the research community to develop an appropriate "conservatism factor" that could sufficiently mitigate possible overestimations of project reductions that stem from uncertainty in nitrous oxide quantification.

This approach is consistent with the Regional Greenhouse Gas Initiative's (RGGI) treatment of nitrous oxide. Under the RGGI Model Rule (January 5, 2007) project developers do not receive credit for reductions in nitrous oxide. The CDM "Consolidated baseline methodology for GHG emission reductions from manure management systems" (ACM0010 V.2) and the U.S. EPA Climate Leaders, Draft Manure Offset Protocol (October 2006) on the other hand allow project developers to calculate decreases in nitrous oxide emissions from sources up to, but excluding, land application.

[8] See IPCC 2006 Guidelines volume 4, chapter 10, table 10.21 and volume 4, chapter 11, table 11.3.

[9] Uncertainty also exists with estimations of baseline methane emission. The Registry takes steps to reduce this uncertainty by following a calculation approach that is based on the monthly biological performance of the operation's anaerobic manure handling systems that existed pre-project, as predicted by the van't Hoff-Arrhenius equation using site-specific data on temperature, VS loading, and system VS retention time. Furthermore, all existing estimates of uncertainty (of which the Registry is aware) involve the quantification of nitrous oxide at a national level, not a project-level. The Registry has been working to evaluate project-level uncertainty. This work is ongoing, but early results suggest that uncertainty levels associated with the quantification of nitrous oxide are more substantial than methane.

Table 1 relates GHG source categories to sources and gasses, and indicates inclusion in the calculation methodology. It is intended to be illustrative – GHG sources are indicative for the source category, GHGs in addition to the main GHG are also mentioned, where appropriate.

Table 1: Manure management source categories, GHG sources, associated gases, and coverage in the manure management project boundary

GHG Source Category	GHG Source	Associated GHGs*	Included in Project Boundary
Waste Production (animal housing and confinement)	• Enteric fermentation	Methane	➢ *Not included* (no change due to project)[10]
	• Waste deposits barn, milking parlor, or pasture/corral	Nitrous oxide	➢ *Not Included*
	• Support equipment	Carbon dioxide	➢ *Included*
Waste Collection and Transport	• Emissions from mechanical systems used to collect and transport waste (e.g., engines and pumps for flush systems; vacuums and tractors for scrape systems)	Carbon dioxide	➢ *Included*
	• Vehicle emissions (e.g., for centralized digesters)	Carbon dioxide	➢ *Included*
Waste Treatment and Storage	• Dry lot deposits	Methane Nitrous oxide	➢ *Included* ➢ *Not Included*
	• Compost piles	Methane Nitrous oxide	➢ *Included* ➢ *Not Included*
	• Solid storage piles	Methane Nitrous oxide	➢ *Included* ➢ *Not Included*
	• Manure settling basins	Methane Nitrous oxide	➢ *Included* ➢ *Not Included*
	• Anaerobic lagoons	Methane Nitrous oxide	➢ *Included* ➢ *Not Included*
	• Aerobic treatment	Carbon dioxide (from aeration equipment)	➢ *Included*
	• Storage ponds	Methane Nitrous oxide	➢ *Included* ➢ *Not Included*
	• Support equipment	Carbon dioxide	➢ *Included*

[10] A livestock operator could change its feeding strategy to maximize biogas production from a digester; thus impacting enteric fermentation emissions from ruminant animals. However, this is an unlikely scenario. Project developers should disclose whether their feeding regimes change to optimize biogas production. If this occurs, the Registry will work with them to incorporate these emissions into the calculation procedure.

GHG Source Category	GHG Source	Associated GHGs*	Included in Project Boundary
Waste Disposal	• Land application • Vehicle emissions (for land application and/or offsite transport)	Nitrous oxide Carbon dioxide	➢ *Not Included* ➢ *Included*
Biogas controls system	• Uncombusted or leaked gas • Biogas combustion • Grid-electricity	Methane Carbon dioxide Carbon dioxide	➢ *Included* ➢ *Not Included* ➢ *Not Included*

* Nitrous emissions could stand for either direct, indirect or both

V. GHG Reductions Calculation Methods

The Reserve's GHG reduction calculation method is derived from the Kyoto Protocol's Clean Development Mechanism (ACM0010 V.2), the EPA's Climate Leaders Program (Draft Manure Management Offset Protocol, October 2006), and the RGGI Model Rule (January, 5 2007).

Quantifying the GHG impact associated with installing a biogas control system is represented by Equation 1, wherein GHG reductions equal baseline emissions minus project emissions.[11]

Equation 1: GHG reductions from installing a biogas control system

$$\text{GHG Reductions} = (\text{Baseline emissions}_{CH4,\ CO2}) - (\text{Project emissions}_{CH4,\ CO2})$$

Total GHG reductions are registered on an annual basis, thus projects will have yearly baseline and project (actual) emissions. But project developers should take note that some equations to calculate baseline and project emissions are run on a month-by-month basis and activity data monitoring have varying levels of frequency. As applicable, monthly baseline emissions are summed together as well as monthly project emissions for the annual comparison.

To support project developers and facilitate consistent and complete emissions reporting, the California Registry's on-line reporting tool (CARROT) will incorporate the equations in this protocol.[12] Until CARROT becomes operational the Reserve will provide spreadsheet-based calculation tools.

Models that estimate biological and physical processes, such as the nitrogen and carbon cycles in soils and biological waste streams, are becoming increasingly available. Process models typically rely on a series of input data that research has shown to be important drivers of the geochemical process. In terms of GHG emissions models, process models

[11] The calculation procedure only addresses direct emissions sources and does not incorporate changes in electricity consumption, which impacts indirect emissions associated with power plants owned and operated by entities other than the livestock operator.
[12] For more information on CARROT, see the Registry's website, www.climateregistry.org

identify the mathematical relationships between inputs, basic conditions, and GHG emissions. At this time, biogeochemical models to assess carbon and nitrogen cycling from waste management systems are under development. The Reserve anticipates incorporating them into this protocol as they become available and verified.

Baseline emissions

Baseline emissions represent the GHG emissions within the project boundary that would have occurred if not for the installation of the biogas control system.[13] For the purposes of this protocol, project developers calculate their baseline emissions according to the manure management system in-place prior to installing the biogas control system. This is referred to as a "continuation of current practices" baseline scenario. Additionally, project developers calculate baseline emissions each year of the project.[14] The procedure assumes there is no biogas control system in the baseline system.

Regarding new livestock operations that install a biogas control system, project developers establish a baseline scenario using the prevailing system type in use for the geographic area, animal type, and farm size that corresponds to their operation.

Baseline emissions include

- Methane emissions
- Carbon dioxide emissions (if necessary)

Project developers separately calculate methane and carbon dioxide, which are then summed for total annual baseline GHG emissions. Information on Activity Data for variables in the methane and carbon dioxide equations is provided in Section VI, Project Monitoring.

Baseline methane emissions. The procedure to determine baseline methane emissions follows Equation 2a, which combines Equation 2b and 2c.

Equation 2b calculates methane emissions from anaerobic manure storage/treatment systems based on site-specific information on the mass of volatile solids degraded by the anaerobic storage/treatment system and available for methane conversion.[15] It incorporates the effects of temperature through the van't Hoff-Arrhenius ('*f*' factor) and accounts for the retention of volatile solids through the use of monthly assessments. Equation 2c is less intensive and applies to non-anaerobic storage/treatment systems. Both Equation 2b and 2c reflect basic biological principles of methane production from available volatile solids, determine methane generation for each livestock category, and account for the extent to which the waste management system handles each category's manure.

---

[13] Projects that co-digest non-livestock waste show that the organic matter added to the biogas control system would have been managed under anaerobic conditions in the absence of the project. For these cases, the Registry will work with the project developer to calculate the co-digested material's contribution to baseline emissions.

[14] Conversely, under a "static baseline," a project developer would assess baseline emissions once before project implementation and use that value throughout the project lifetime.

[15] Anaerobic storage/treatment systems generally refer to anaerobic lagoons, or storage ponds, etc.

Equation 2a: Baseline methane emissions

$$BE_{CH4,y} = \sum_{S,L} BE_{CH4,AS,y} + BE_{CH4,non-AS,y}$$

Where,

$BE_{CH4,y}$	=	total annual baseline methane emissions, expressed in carbon dioxide equivalent (CO_2e)
$BE_{CH4,AS,L,y}$	=	total annual baseline methane emissions from anaerobic storage/treatment systems by livestock category 'L', expressed in carbon dioxide equivalent (CO_2e)
$BE_{CH4,non\text{-}AS,L,y}$	=	total annual baseline methane emissions from non-anaerobic storage/treatment systems, expressed in carbon dioxide equivalent (CO_2e)

Equation 2b: Baseline methane emissions from anaerobic storage/treatment systems

$$BE_{CH4,AS,y} = \sum_{L,AS} VS_{\deg,AS,L,y} \times B_{0,L} \times 0.67 \times 0.001 \times 21$$

Where,

$BE_{CH4,AS,y}$	=	total annual baseline methane emissions from anaerobic manure storage/treatment systems, expressed in carbon dioxide equivalent (CO_2e)
$VS_{deg,AS,L,y}$	=	annual volatile solids degraded in anaerobic manure storage/treatment system 'AS' from livestock category 'L' (kg dry matter)
$B_{0,L}$	=	maximum methane producing capacity of manure for livestock category 'L' (m^3 CH_4/kg of VS) – Appendix B, Table B.3
0.67	=	methane density conversion factor, m^3 to kg (at 20 °C and 1 atm pressure)
0.001	=	conversion factor from kg to metric tonnes
21	=	Global Warming Potential factor of methane to carbon dioxide equivalent

$$VS_{\deg,L,AS,y} = \sum_{AS,L} VS_{avail,AS,L} \times f$$

Where,

$VS_{deg,AS,L,y}$	=	annual volatile solids degraded by anaerobic manure storage/ treatment system 'AS' by livestock category 'L' (kg dry matter)
$VS_{avail,AS,L}$	=	monthly volatile solids available for degradation from anaerobic manure storage/treatment system 'AS' by livestock category 'L'(kg dry matter)
f	=	"the proportion of volatile solids that are biologically available for conversion to methane based on the monthly temperature of the system"[16]

[16] Mangino, et al.

$$VS_{avail,AS,L} = \left(VS_{in,L} \times P_L \times MS_{AS,L} \times dpm \times 0.8\right) + \left(VS_{avail-1,AS} - VS_{\deg-1,AS}\right)$$

Where,

$VS_{avail,AS,L}$	=	monthly volatile solids available for degradation in anaerobic storage/treatment system 'AS' by livestock category 'L'(kg dry matter)[17]
$VS_{in,L}$	=	volatile solids produced by livestock category 'L' on a dry matter weight basis (kg/animal/day) – calculated according to Equation 2d (for "dominant" livestock categories) or found in Appendix B, Table B.3 and B.4
$P_{l,}$	=	population of livestock category 'L'
$MS_{AS,L}$	=	percent of manure sent to (managed in) anaerobic manure storage/treatment system 'AS' from livestock category 'L' (%)*
dpm	=	days per month
0.8	=	system calibration factor[18]
$VS_{avail-1,AS}$	=	previous month's volatile solids available for degradation in anaerobic system 'AS' (kg)
$VS_{deg-1,AS}$	=	previous month's volatile solids degraded by anaerobic system 'AS' (kg)[19]

$$f = \exp\left[\frac{E\left(T_2 - T_1\right)}{RT_1T_2}\right]$$

Where,

f	=	the van't Hoff-Arrhenius factor
E	=	activation energy constant (15,175 cal/mol)
T_1	=	303.16K
T_2	=	ambient temperature (K = °C + 273)
R	=	ideal gas constant (1.987 cal/Kmol)

If $T_2 < 5$ °C then $f = 0.104$

* The MS value represents the percent of manure that would be sent to (managed by) the anaerobic manure storage/treatment systems in the baseline case – as if the biogas control system was never installed.

[17] The RGGI Model Rule (January 5, 2007) provides a site-specific method to assess the VS available, which is not differentiated by livestock category, but based on a sampling approach of the waste entering the anaerobic storage/treatment system. If project developers follow the RGGI approach they must demonstrate that the VSin value is representative of what the baseline VS loading would be.

[18] Mangino, et al. This factor was derived to "account for management and design practices that result in the loss of volatile solids from the management system." Project developers should assess its relevance to their system and include or adjust it accordingly.

[19] The difference between VSavail-1 and VSdeg-1 represents VS retained in the system and not removed at month's end; thus VS could accumulate over time. However, project developers should not carry-over volatile solids from one month to the next after a system has been cleaned out, such as temporary storage ponds or tanks where the VS-retention time might be 30 days. For these systems project developers do not add "(VSavail-1 – VSdeg-1)."

Consistent with ACM0010 (V2 p.2), project developers demonstrate that the depth of their anaerobic ponds/lagoons pre-project sufficiently prevent algal oxygen production and create an oxygen-free bottom layer, which usually means at least 1 meter. Ultimately, to generate methane emissions anaerobic systems should be designed and maintained with sufficient volume to properly treat volatile solids and prevent solids from accumulating, to the extent that they adversely impact the treatment zone.

Additional information on the design and maintenance of anaerobic manure storage/treatment systems is available through USDA NRCS Standards. See U.S. Department of Agriculture Natural Resources Conservation Service, Conservation Practice Standard, Waste Storage Facility, No. 313; and U.S. Department of Agriculture Natural Resources Conservation Service, Conservation Practice Standard, Waste Treatment Lagoon, No. 359

Equation 2c: Baseline methane for non-anaerobic storage/treatment systems

$$BE_{CH4,nAS,y} = \left(\sum_{L,S} P_{L,y} \times MS_{L,nAS} \times \frac{Mass_L}{1{,}000kg} \times VS_{in,L} \times 365 \times MCF_{nAS} \times B_{0,L} \right) \times 0.67 \times 0.001 \times 21$$

Where,

$BE_{CH4,nAS,y}$	=	total annual baseline methane emissions from non-anaerobic storage/treatment systems, expressed in carbon dioxide equivalent (CO_2e)
$P_{l,}$	=	population of livestock category 'L'
$MS_{L,nAS}$	=	percent of manure from livestock category 'L' managed in non-anaerobic storage/treatment systems (%)
$Mass_L$	=	average live weight for livestock category 'L' (kg)
$VS_{in,L}$	=	volatile solids produced by livestock category 'L' on a dry matter basis (kg/animal/day) – calculated according to Equation 2d (for "dominant" livestock categories) or found in Appendix B, Table B.3 and B.4
365	=	days in a year
$MCF_{,nAS}$	=	methane conversion factor for non-anaerobic storage/treatment system 'S' (%) – See Appendix B, Table B.5
$B_{0,L}$	=	maximum methane producing capacity for manure for livestock category 'L' (m^3 CH_4/kg of VS dry matter) – Appendix B, Table B.3
0.67	=	methane density conversion factor, m^3 to kg (at 20°C and 1 atm pressure)
0.001	=	conversion factor from kg to metric tonnes
21	=	Global Warming Potential factor of methane to carbon dioxide equivalent

***** The MS value represents where manure that would be sent to (managed by) in the baseline case; as if the biogas control system was never installed.

Baseline methane calculation variables. The calculation procedure uses a combination of site-specific values and default factors.[20]

Population – P_L. The procedure requires project developers to differentiate between livestock categories ('L') – e.g., lactating dairy cows, non-milking dairy cows, heifers, etc. This accounts for differences in methane generation across livestock categories. See Appendix B, Table 2. The population of each livestock category is monitored on a monthly basis, and for Equation 2c averaged for an annual total population.

Volatile solids – VS_{in}. This value represents the annual organic material in the manure for each livestock category and consists of both biodegradable and non-biodegradable fractions. The VS content of manure is a combination of excreted fecal material (the fraction of a livestock category's diet consumed and not digested) and urinary excretions, expressed in a dry matter weight basis (kg/animal).[21]

This procedure requires that the VS value for "dominant" livestock categories be determined according to either of the two options in Equation 2b. Option 1 is from the U.S. GHG Inventory; Option 2 is from ACM0010 (V2, p.8). A "dominant" livestock category is one that contributes at least 40% of the VS entering a manure storage pond and/or anaerobic lagoon under baseline conditions – i.e., pre digester installation.[22]

For all other livestock categories VS values are found in Appendix B, Table B.3 or Table B.4. The Reserve encourages project developers to calculate VS for every livestock category based on site-specific data.

For Equation 2b, VS_{in} equals the result of Equation 2d, or the VS value from Appendix B, Table B.3 or B.4, depending on the livestock category.

Equation 2d: Daily volatile solids for "dominant" livestock category

Option 1

$$VS_L = \left(\frac{GE_L - DE_L + (0.02 \times GE_L)}{20.1} \right)$$

Where,

VS_L	=	volatile solid excretion on a dry matter weight basis (kg/animal/day)
GE_L	=	average daily gross energy intake of feed (MJ/animal/day)
DE_L	=	average daily digestible energy of the feed (MJ/animal/day)
0.02	=	urinary energy excretion factor
20.1	=	conversion of dietary gross energy to dry organic matter (MJ/kg)

[20] The Registry permits and encourages project developers to refine the calculation where appropriate with site-specific information. Justification and supporting documentation for the site-specific variables must be provided to project verifiers.

[21] IPCC 2006 Guidelines volume 4, chapter 10, p. 10.42.

[22] The basis for the 40% cutoff is to maximize the use of site-specific data to determine the available VS that is converted to methane in the anaerobic storage ponds and treatment lagoons. The Registry will work with project developers to reasonably apply the "dominant" classification.

Option 2

$$VS_L = \left(GE_L \times \left(1 - \frac{DE_L}{100} \right) + (UE \times GE_L) \right) \times \left(\frac{1 - ASH}{ED_L} \right)$$

Where,

VS_L	=	volatile solid excretion on a dry matter weight basis (kg/animal/day)
GE_L	=	average daily gross energy intake (MJ/animal/day)
DE_L	=	average daily digestible energy of the feed (%)
UE x GE_L	=	urinary energy expressed as a fraction of GE (%). Typically, (0.04 x GE) can be considered urinary energy excretion by most ruminants (reduce to 0.02 for ruminants fed with 85% or more grain in the diet or for swine).
ASH	=	average daily ash content of manure expressed as a fraction of the dry matter feed intake (%) – e.g., 0.08 for cattle[23]
ED_L	=	Energy density of the feed in MJ/kg fed to livestock category 'L'[24]

$Mass_L$. This value is the annual average live weight of the animals, per livestock category. Default VS values correspond to a livestock category's average mass. Note that for "dominant" livestock categories that calculate VS according to Equation 2b this variable equals zero.

Maximum methane production – $B_{0,L}$. This value represents the maximum methane-producing capacity of the manure, differentiated by livestock category ('L') and diet. Project developers use the default B_0 factors from Appendix B, Table B.3.

MS. The MS value apportions manure from each livestock category to appropriate manure management system component ('S'). It reflects the reality that waste from the operation's livestock categories are not managed uniformly. For example, before land application a dairy operation might send 85% of its milking cow's waste to an anaerobic lagoon and 15% could be deposited in a corral. The MS value accounts for the operation's multiple types of manure management systems. It is expressed as a percent (%), relative to the total amount of waste produced by the livestock category.

Importantly, the MS value indicates where the waste would be managed in the baseline scenario – i.e., where the manure would end-up if the digester was never installed.

Methane conversion factor – MCF. Each manure management system component has a volatile solids-to-methane conversion efficiency, which represents the degree to which maximum methane production (B_0) is achieved. Methane production is a function of the

---

[23] IPCC 2006 Guidelines volume 4, chapter 10, p. 10.42.

[24] IPCC notes the energy density of feed, ED, is typically 18.45 MJ/kg on a dry matter basis, which is relatively constant across a wide variety of grain-based feeds. IPCC 2006 Guidelines volume 4, chapter 10, p. 10.42. The project developer will record the composition of the feed to enable the verifier to verify the energy density of the feed.

extent of anaerobic conditions present in the system, the temperature of the system, and the retention time of organic material in the system.[25]

According to this protocol and similar to the RGGI Model Rule (January, 5, 2007), for anaerobic lagoons, storage ponds, liquid slurry tanks, etc, project developers perform a site-specific calculation of the mass of volatile solids degraded by the anaerobic storage/treatment system. This is expressed as “degraded volatile solids or VS_{deg}” in Equation 2b, which equals the system’s monthly available volatile solids multiplied by “f,” the van’t Hoff-Arrhenius factor. The ‘f’ factor effectively converts total available volatile solids in the anaerobic manure storage/treatment system to methane-convertible volatile solids, based on the monthly temperature of the system.

Multiplying “VS_{deg}” by “B_0” site a site-specific representation of the uncontrolled methane emissions would have occurred in the absence of a digester – from the anaerobic storage and/or treatment system, taking into account each livestock category’s contribution of manure to that system.

This method to calculate methane emissions reflects the site-specific monthly biological performance of the operation’s anaerobic manure handling systems that existed pre-project, as predicted by the van’t Hoff-Arrhenius equation using farm-level data on temperature, VS loading, and system VS retention time.[26]

Default MCF values for non-anaerobic manure storage/treatment are available in Appendix B, Table B.5, which are used for Equation 2c. Project developers do not use the default “anaerobic lagoons” and “liquid/slurry” MCF.

Baseline carbon dioxide emissions. Project developers only calculate baseline carbon dioxide emissions from the following sources:

- mobile combustion and
- stationary combustion.

For mobile and stationary combustion sources, project developers multiply the quantity of fuel consumed by a fuel-specific emission factor, see Equation 3 below. Examples of sources include fossil fuel generators to power pumping systems or milking parlor equipment, Bobcats that operate in barns or freestalls, or manure hauling trucks.

Mobile sources include vehicles that transport manure off-site.

For additional information on calculating mobile and stationary combustion sources project developers can refer to the guidance in the California Registry’s General Reporting Protocol, Chapter 7 and 8.

[25] IPCC 2006 Guidelines volume 4, chapter 10, p. 10.43.
[26] The method is derived from Mangino et al., “Development of a Methane Conversion Factor to Estimate Emissions from Animal Waste Lagoons”

Equation 3: Baseline carbon dioxide emissions

$$CO_{2,MSC} = \left(\sum_{c} QF_c \times EF_{CO2,f} \right) \times 0.001$$

Where,

$CO2_{MSC}$	=	carbon dioxide emissions (tCO2/yr) from Mobile and Stationary Combustion sources
$EF_{CO2,f}$	=	fuel-specific emission factor f (kg CO_2/MMBTU), General Reporting Protocol Appendix C.3 and C.5
QF_c	=	quantity of fuel consumed for each mobile and stationary emission source 'c' (MMBTU/yr)
0.001	=	conversion factor from kg to metric tonnes

As stated above, sources of carbon dioxide within the manure management system might not change as a result of the project, or could be insignificant. Therefore, project developers may conduct an assessment of the change in direct anthropogenic carbon dioxide emissions due to the project to determine if baseline and project carbon dioxide emissions need to be calculated on an annual basis. Project developers are only required to conduct an annual assessment of carbon dioxide emissions if project carbon dioxide emissions exceed 5% of baseline, from mobile and stationary combustion sources.[27]

Project emissions

Project emissions are actual GHG emissions that occur within the project boundary after the installation of the biogas control system. Project emissions are calculated on an annual, *ex-post* basis. But like baseline emissions, some parameters are monitored on a monthly basis

Project emissions include

- Methane emissions
- Carbon dioxide emissions (if necessary)

Project developers separately calculate methane and carbon dioxide, which are summed together for total project GHG emissions.

Project methane emissions. As shown in Equation 4, project methane emissions equal

- the amount of methane from waste treatment and storage not captured and combusted by the control system, plus
- methane from the digester effluent storage pond (if necessary), plus
- methane from sources in the waste treatment and storage category other than the biogas control system and associated effluent pond.

[27] This is consistent with guidance in the Registry's GRP and WRI's GHG Project Protocol regarding the treatment of significant secondary effects.

Consistent with ACM0010 and this protocol's baseline methane calculation approach, the formula to account for project methane emissions incorporates all potential sources within the waste treatment and storage category. Non-biogas control system-related sources follow the same calculation approach as provided in the baseline methane equations. Several activity data for the variables in Equation 4c will be the same as those in Equation 2a – 2c.

Equation 4: Project methane emissions

$$\text{Project methane } (CO_2e) = [CH_4\,(BCS) + CH_4\,(EP) + CH_4\,(\text{non BCS-related sources})] \times 21$$

Where,

Project methane (CO_2e)	=	total project methane emissions (tCO_2e/yr)
CH_4 (BCS)	=	methane emissions from the Biogas Control System (tCH_4/yr) – calculated below
CH_4 (EP)	=	methane emissions from the BCS Effluent Pond (tCH_4/yr) – calculated below
CH_4 (non BCS-related sources)	=	methane from sources in the waste treatment and storage category other than the Biogas Control System and associated Effluent Pond (tCH_4/yr) – calculated below
21	=	Global Warming Potential factor of methane to carbon dioxide equivalent

Equation 4a: Project methane emissions from the biogas control system

$$CH_4(BCS) = (CH_4Combusted)\left(\frac{1}{BCE \times BDE} - 1\right)$$

Where,

CH_4 (BCS)	=	methane emissions from the Biogas Control System (tCH_4/yr)
CH_4 (Combusted)	=	methane emissions combusted in the Biogas Control System (tCH_4/yr)[28]
BCE	=	methane collection efficiency of the BCS (%)
BDE	=	methane destruction efficiency of the BCS (%)

[28] This value reflects directly measured biogas flow rate and methane concentration in the biogas to the combustion device.

Equation 4b: Project methane emissions from the BCS effluent pond[29]

$$CH_4(EP) = VS_{ep} \times B_{o,ep} \times 365 \times 0.67 \times MCF_{ep} \times 0.001$$

Where,

CH_4 *(EP)*	=	methane emissions from the Effluent Pond (tCH_4/year)
VS_{ep}	=	volatile solid to effluent pond (kg/day) – 30% of the VS entering the digester[30]
$B_{o,ep}$	=	maximum methane producing capacity (m^3CH_4/kg of VS dry matter)*
365	=	number of days in a year
0.67	=	conversion factor for m^3 to kg
MCF_{ep}	=	methane conversion factor (%), Appendix B, Table B.5. Project developers should use the *liquid slurry* MCF value
0.001	=	conversion factor from kg to metric tones

* The B_o value for the project effluent pond is not differentiated by livestock category. Project developers could use the B_o value that corresponds with an average of the operation's livestock categories that contributes manure to the biogas control system, or use a justified alternative value.

Equation 4c: Project methane emissions from *non*-BCS-related sources*

$$CH_4(nonBCSsources) = \left(\sum_l EF_{CH4,l}(nBCSs) \times P_l \right) \times 0.001$$

Where,

CH_4 *(non BCS-related sources)*	=	methane from sources in the waste treatment and storage category other than the Biogas Control System and associated Effluent Pond (tCH_4/yr)
$EF_{CH4,L}$ *(nBCSs)*	=	emission factor for the livestock population ($kgCH_4$/head/year) from non-BCS-related sources – (calculated below)
P_L	=	population of livestock category 'L'
0.001	=	conversion factor from kg to metric tonnes

$$EF_{CH4,L}(nBCSs) = \left(VS_L \times \frac{Mass_L}{1{,}000kg} \times B_{o,L} \times 365 \times 0.67 \right) \times \left(\sum_S MCF_S \times MS_{L,S} \right)$$

Where,

$EF_{CH4,L}$ *(nBCSs)*	=	methane emission factor for the livestock population ($kgCH_4$/head/year) from non-BCS-related sources
VS_L	=	daily volatile solid excretion for each livestock category 'L' (kg dry matter/day), Appendix B, Table B.3 and B.4
$Mass_L$	=	average live weight for livestock category 'L' (kg)

[29] If no effluent pond exists and project developers send digester effluent (VS) to compost piles or apply directly to land, for example, then the VS for these cases should also be tracked.
[30] Per ACM0010 (V2 Annex I).

$B_{o,L}$	=	maximum methane producing capacity for manure for livestock category 'L' (m^3 CH_4/kg of VS dry matter), Appendix B, Table B.3 or B.4
365	=	number of days in a year
0.67	=	conversion factor for m^3 to kg
MCF_S	=	methane conversion factor for system component 'S' (%), Appendix B, Table B.5
$MS_{L,S}$	=	percent of manure from livestock category l that is managed in system component 'S' (%)

* According to this protocol, non-BCS-related sources means manure management system components (system component 'S') other than the biogas control system and the BCS effluent pond (if used).

Project carbon dioxide emissions. Like the baseline approach, the procedure to assess project carbon dioxide emissions only incorporates

- mobile combustion sources and
- stationary combustion sources.

As stated above, project developers are only required to conduct an annual assessment of carbon dioxide emissions in cases where project carbon dioxide emissions exceed 5% of baseline. If this occurs, project developers use Equation 3 above to calculate project carbon dioxide emissions (multiply the quantity of fuel consumed by a fuel-specific emission factor).

Carbon dioxide emissions from biogas control systems are considered biogenic emissions (as opposed to anthropogenic) and will not be included in the project emissions.

VI. Project Monitoring

Project developers are responsible for monitoring the performance of the project and operating the biogas control system in a manner consistent with the manufacturer's recommendations. According to this protocol, methane emissions from the biogas control systems are monitored with measurement equipment that directly meter

- the continuous rate of biogas flow and
- the methane concentration of the biogas to the combustion devices, on a quarterly basis.

Monitoring instruments shall be calibrated and maintained as specified by the manufacturer.

Provisions for monitoring other variables to calculate baseline and project emissions are provided in the tables below (adapted from ACM0010, V.2). The parameters are organized by general project factors then by the calculation methods.

General project parameters

Parameter:	Regulations
Data unit:	Air and water quality
Description:	Existence and enforcement of relevant air water quality regulations
Source of data:	Air and water quality control boards or management districts, state-level EPA
Monitoring frequency:	Once, at beginning of project
Comments:	1) To demonstrate ability to meet the Regulatory Test – where regulation would require the installation of a biogas control system. 2) To demonstrate compliance with associated environmental rules, e.g., criteria pollutant and effluent discharge limits.
Verification comment	Determine regulatory agencies responsible for regulating livestock operation; Review regulations pertinent to livestock operation

Parameter:	L
Data unit:	Livestock categories
Description:	Type of livestock categories on the farm
Source of data:	Project developer, based on operating records.
Monitoring frequency:	Monthly
Comments:	Select from list provided in the Manure Management Project Reporting Protocol, Appendix B, Table B.2.
Verification comment:	Review herd management software; Conduct site visit; Interview operator.

Parameter:	MS_L
Data unit:	Percent (%)
Description:	Manure management system components. Type of manure storage and treatment components used by livestock operator.
Source of data:	Project developer, based on operating records.
Monitoring frequency:	Monthly
Comments:	Reflects the percent of waste handled by the system components 'S' that would manage manure in the baseline case – as if the project was never installed. Applicable to the entire operation. Within each livestock category, the sum of MS values (for all treatment/storage systems) equals 100%. Select from list provided in Appendix B, Table B.1.
Verification comment	Conduct site visit; Interview operator.

Parameter:	P_L
Data unit:	Population (# head)
Description:	Average number of animals contributing manure to the manure management system by each livestock category
Source of data:	Project developer, based on operating records on herd size.
Measurement procedures (if applicable):	
Monitoring frequency:	Monthly
Comments:	
Verification comment	Review herd management software; Review local air and water quality agency reporting submissions, if available (e.g., in CA, dairies with more than 500 cows report farm information to CARB)
Parameter:	$Mass_L$
Data unit:	Kg
Description:	Average live weight by livestock category (divided by 1,000kg)
Source of data:	Project developer. Calculated from operating records.
Measurement procedures (if applicable):	
Monitoring frequency:	Monthly
Comments:	Conduct site specific Interview livestock operator Review Average Daily Gain records

Parameter:	T
Data unit:	^{o}C
Description:	Average temperature at location of the operation
Source of data:	Project developer, based on National Weather Service data
Measurement procedures (if applicable):	
Monitoring frequency:	Monthly
Comments:	Used to choose MCF value
Verification comment	Review temperature records obtained from weather service

Baseline methane calculation variables

Parameter:	$B_{0,L}$
Data unit:	Fraction (m^3 CH_4/kgVS)
Description:	Maximum methane producing capacity for manure by livestock category
Source of data:	Manure Management Project Reporting Protocol, Appendix B, Table B.3, "Volatile Solids and Maximum Methane Potential by Livestock Category"
Monitoring frequency:	Annual
Comments:	
Verification comment:	

Parameter:	MCF_S
Data unit:	Percent
Description:	Methane conversion factor for manure management system component 'S'
Source of data:	Appendix B, Table B.5, (From IPCC v.4, Chapter 10, Table 10.17)
Monitoring frequency:	Annual
Comments:	Differentiate by livestock category
Verification comment:	Review value from look-up table

Parameter:	$VS_{in,L}$ (dominant)
Data unit:	Kg dry matter/day
Description:	Daily volatile solid excretion
Source of data:	Project developer
Measurement procedures (if applicable):	A calculated value
Monitoring frequency:	Monthly.
Comments:	Applicable to livestock categories that contribute at least 40% of the waste to baseline anaerobic storage/treatment systems; Calculated from GE, DE values.
Verification comment:	Review nutritionist rationing regime records. Review feed supplier information.

Parameter:	GE_L
Data unit:	MJ/day
Description:	Average daily gross energy intake for each livestock category
Source of data:	Project developer, based on operating records and/or nutritionist data
Monitoring frequency:	Monthly.
Comments:	Used to calculate VS (dominant category)
Verification comment	Review nutritionist rationing regime records. Review feed supplier information.

Parameter:	DE_L
Data unit:	Fraction (%)
Description:	Average digestible energy of the feed for each livestock category
Source of data:	Project developer, based on operating records and/or nutritionist data
Monitoring frequency:	Monthly.
Comments:	Used to calculate VS (dominant category)
Auditor	Review nutritionist rationing regime records. Review feed supplier information.

Parameter:	UE
Data unit:	Fraction (%)
Description:	Urinary energy expressed as a fraction of GE for each livestock category
Source of data:	Project developer, based on operating records and/or nutritionist data
Monitoring frequency:	Monthly.
Comments:	Used to calculate VS (dominant category)
Auditor	Review nutritionist rationing regime records. Review feed supplier information.

Parameter:	ASH
Data unit:	Fraction of the dry matter feed intake (%)
Description:	Ash content of the manure calculated as a fraction of the dry matter feed intake
Source of data:	Project developer, based on operating records and/or nutritionist data
Measurement procedures (if applicable):	
Monitoring frequency:	Monthly
Comments:	Used to calculate VS (dominant category)
Auditor	Review nutritionist rationing regime records. Review feed supplier information.

Parameter:	ED_L
Data unit:	MJ/kg
Description:	Average energy density of the feed
Source of data:	Project developer, based on operating records and/or nutritionist data
Measurement procedures (if applicable):	
Monitoring frequency:	Monthly.
Comments:	Used to calculate VS (dominant category)
Auditor	Review nutritionist rationing regime records. Review feed supplier information.

Parameter:	$VS_{in,L}$ (non-dominant categories)
Data unit:	Kg dry matter/animal/day
Description:	Daily volatile solid excretion for each livestock category
Source of data:	Appendix B, Table B.3 and Table B.4, "Volatile Solids and Maximum Methane Potential by Livestock Category."
Measurement procedures (if applicable):	
Monitoring frequency:	Annual
Comments:	

Parameter:	VS_{avail}
Data unit:	Kg dry matter
Description:	Monthly volatile solid available for degradation for each livestock category
Source of data:	Project developer. Calculated value from operating records.
Measurement procedures (if applicable):	
Monitoring frequency:	Monthly
Comments:	

Parameter:	VS_{deg}
Data unit:	Kg dry matter
Description:	Daily volatile solid excretion for each livestock category
Source of data:	Project developer. Calculated value from operating records.
Measurement procedures (if applicable):	
Monitoring frequency:	Monthly
Comments:	

Parameter:	f
Data unit:	
Description:	van't Hoff-Arrhenius equation
Source of data:	Project developer. Calculated from temperature.
Measurement procedures (if applicable):	
Monitoring frequency:	Monthly
Comments:	The proportion of volatile solids that are biologically available for conversion to methane based on the monthly temperature of the system

Project methane calculation variables – BCS + Effluent Pond

Parameter:	CH_4(combusted)
Data unit:	tCH_4
Description:	Amount of methane combusted in biogas control system
Source of data:	Project developer. Based on meter reading data.
Measurement procedures (if applicable):	See "V" and "CH4-fraction" parameters below.
Monitoring frequency:	
Comments:	Calculated from biogas flow and methane fraction.
Verification comment	Review meter reading data. Confirm proper operation, in accordance with the manufacturer's specifications.

Parameter:	V
Data unit:	scf/m
Description:	Biogas flow from digester to combustion devices
Source of data:	Project developer.
Measurement procedures (if applicable):	Direct measurement
Monitoring frequency:	Continuous metering
Comments:	Calculated by biogas control system metering equipment; corrects for temperature and pressure
Verification comment:	Review meter reading data Confirm proper operation, in accordance with the manufacturer's specifications.

Parameter:	CH_4-fraction
Data unit:	%
Description:	Fraction of biogas
Source of data:	Project developer.
Measurement procedures (if applicable):	Direct measurement
Monitoring frequency:	Quarterly metering
Comments:	Use a direct sampling approach that yields a value with at least 95% confidence. Calibrate monitoring instrument in accordance with the manufacturer's specifications.
Verification comment:	Review meter reading data. Confirm proper operation, in accordance with the manufacturer's specifications.

Parameter:	BDE
Data unit:	%
Description:	Biogas destruction efficiency of the biogas control system, accounts for incomplete combustion.
Source of data:	Manufacture rating for primary combustion device and flare
Measurement procedures (if applicable):	
Monitoring frequency:	Monthly
Comments:	Reflects the actual efficiency of the system to burn captured gas Accounts for different combustion devices.
Verification comment:	Confirm proper operation, in accordance with the manufacturer's specifications.

Parameter:	BCE
Data unit:	%
Description:	Biogas capture efficiency of the anaerobic digester, accounts for gas leaks.
Source of data:	Manufacture rating
Measurement procedures (if applicable):	
Monitoring frequency:	Monthly
Comments:	

Parameter:	VS_{ep}
Data unit:	Kg dry matter/day
Description:	Average daily volatile solid of digester effluent to effluent pond
Source of data:	Project developer.
Measurement procedures (if applicable):	
Monitoring frequency:	Annually
Comments:	Equals 30% of the VS entering the digester; From ACM0010 (V2 Annex I)
Verification comment:	

Parameter:	Bo_{ep}
Data unit:	Fraction (m^3 CH_4/kgVS)
Description:	Maximum methane producing capacity for manure to effluent pond
Source of data:	An average of the Bo_{ep} value of the operation's livestock categories that contributes manure to the biogas control system, or justified alternative value.
Measurement procedures (if applicable):	
Monitoring frequency:	Annual
Comments:	Not differentiated by livestock category.
Verification comment:	

Parameter:	MCF_{ep}
Data unit:	Fraction
Description:	Methane conversion factor for biogas control system effluent pond
Source of data:	Appendix B, Table B.5, (From IPCC v.4, chapter 10, Table 10.17)
Monitoring frequency:	Annual
Comments:	Project developers should use the *liquid slurry* MCF value
Verification comment	

Project methane calculation variables – non BCS-related sources

Parameter:	$MS_{L,S}$
Data unit:	Fraction
Description:	Fraction of manure from each livestock category managed in manure management system component 'S'
Source of data:	Project developer, based on configuration of manure management system
Measurement procedures (if applicable):	
Monitoring frequency:	Monthly
Comments:	Differentiated by livestock category
Verification comment:	Conduct site visit; Interview operator.

Baseline and project carbon dioxide calculation variables

Parameter:	$EF_{CO2,f}$
Data unit:	Kg CO2/MMBTU
Description:	Fuel-specific emission factor for mobile and stationary combustion sources
Source of data:	California Registry GRP
Monitoring frequency:	Annual
Comments:	If heat or biogas produced from digester is used as an energy source, the EF is zero.
Verification comment:	

Parameter:	QF_c
Data unit:	MMBTU/year
Description:	Fuel used by project for manure collection, transport, treatment/storage, and disposal
Source of data:	Project developer, based operating records (e.g., fuel purchases records)
Measurement procedures (if applicable):	
Monitoring frequency:	Annually
Comments:	Fuel use should be differentiated by mobile and stationary combustion sources
Verification comment	Review fuel purchase records

VII. Reporting Parameters

This section provides guidance on reporting rules and procedures. A priority of the Reserve is to facilitate consistent and transparent information disclosure among project developers. At this time, there is no deminimis reporting provision. All direct methane, carbon dioxide, and nitrous oxide (if necessary) should be reported within the project boundary. Project developers submit annual project reports through the California Registry's on-line reporting tool – CARROT.[31]

Pre-registration reporting forms

Project developers provide the following information to the Reserve before registering reductions associated with installing a biogas control system.[32]

Form 1: General information

1. Name of operation
2. Address (including county)
3. Description of the type of operation (*e.g.,* dairy, swine, *etc.*)
4. If dairy,
    a. Breed (*e.g.,* Holstein, Guernsey, *etc.*)
    b. Average number of lactating cows
    c. Average number of dry cows
    d. Average number of replacements
    e. Respective fraction of the manure from the milking herd, dry cows, and replacements collected for digestion
    f. Type(s) of manure collection system (e.g., scrape, flush, etc.) and frequency of manure collection
5. If swine,
    a. Type of swine operation (e.g., farrow-to-wean, farrow plus nursery, farrow-to-finish, etc.)
    b. Average number of sows and pregnant gilts and number of litters per sow-year
    c. Average number of nursery pigs and number of nursery stage cycles per year
    d. Average number of feeder pigs and number of grow/finish cycles per year
    e. Type(s) of manure collection systems (*e.g.,* flush, pull-plug pit, *etc.*) and frequency of manure collection
6. For animal operations other than those listed above,
    a. Number and ages of animals
    b. Type of manure collection system
7. Diagrammatic representation of the waste management system existing on the project site prior to project implementation.
8. Characterize the anaerobic waste handling system(s) with respect to the specifications provided in Natural Resources Conservation Service Conservation Practice Standard Waste Treatment Lagoon, No. 359, and/or Conservation Practice Standard, Waste Storage Facility, No. 313
9. Description of local and state air and water quality regulations pertinent to the project.

---

[31] Until the Registry's CARROT tool is updated to accept GHG reductions data submitted according to this protocol, spreadsheet-based tools will be provided to project developers.

[32] The pre-registration reporting forms are sourced from the U.S. EPA AgStar's *A Protocol for Quantifying and Reporting the Performance of Anaerobic Digestion Systems for Livestock Manures*.

Form 2: Biogas control system information

1. Type of digester (*e.g.,* mixed, plug-flow, attached film, or covered lagoon)
2. Name of system designer, address, and other contact information
3. Digester design assumptions
   a. Number and type of animals
   b. For lactating cows, average live weight or average milk production
   c. For swine, type or types (*e.g.,* gestating sows, lactating sows, feeder pigs, *etc.*) and average live weight
   d. Manure volume, ft^3/day (m^3/day)
   e. Wastewater volume, ft^3/day (m^3/day) (*e.g.,* none, milking center wastewater, confinement facility wash-down, *etc.*)
   f. Other waste volume(s), ft^3/day (m^3/day) (*e.g.,* none, food processing wastes, *etc.*)
   g. Pretreatment before digestion (*e.g.,* none, gravity settling, stationary screen, screw press, *etc.*)
   h. Treatment of digester effluent (*e.g.,* none, solids separation by screening, *etc.* with details including use or method of disposal)
   i. Method of digester effluent storage (*e.g.,* none, earthen pond, *etc.*)
4. Physical description
   a. General description including types of construction materials (*e.g.,* partially below grade, concrete channel plug-flow with flexible cover, *etc.*)
   b. Dimensions (length and width or diameter and height or depth)
   c. Type(s), location(s), and thickness(s) of insulation
   d. Operating volume and ancillary biogas storage volume if present
   e. Design hydraulic retention time
   f. Design operating temperature
   g. Compliance (yes or no) with the applicable Natural Resources Conservation Service Conservation Practice Standard (No. 365: Anaerobic Digester—Ambient Temperature or No. 366: Anaerobic Digester—Controlled Temperature)

Form 3: Biogas utilization information

1. Biogas utilization (*e.g.,* none, generation of electricity, use on-site as a boiler or furnace fuel, or sale to a third party)
2. If designed to generate electricity,
   a. Type of engine-generator set (*e.g.,* internal combustion engine, micro turbine or fuel cell with the name of the manufacturer, model, power output rating (kW or MJ) for biogas, and nominal voltage
   b. Component integration (factory or owner)
   c. Origin of equipment controller (manufacturer integrated, third party off-the-shelf, or third party custom)
   d. System installer
   e. Pretreatment of biogas (*e.g.,* none, condensate trap, dryer, hydrogen sulfide removal, *etc.* with the names of manufacturers, models, *etc.*)
   f. Exhaust gas emission control (*e.g.,* none, catalytic converter, *etc.*)

g. If interconnected with an electric utility
   - Name of the utility
   - Type of utility contract (e.g., sell all/buy all, surplus sale, or net metering)

h. If engine-generator set waste heat utilization
   - Heat source (e.g., cooling system or exhaust gas or both) and heat recovery capacity (Btu or kJ/hr)
   - Waste heat utilization (*e.g.*, digester heating, water heating, space heating, *etc.*)

3. If designed to use on-site as a boiler or furnace fuel, a description of the boiler or furnace including manufacturer, model, and rated capacity (Btu or kJ/hr)
4. If designed for biogas sale to a third party, a description of the methods of processing, transport, and end use

Reporting cycle

For the purposes of this protocol, project developers report GHG reductions associated with installing a biogas control system that occurred the preceding year. In keeping with the reporting rules of the General Reporting Protocol, the reporting deadline for project developers is August 31 the year following the reduction year, and the verification deadline is December 31.[33]

Project crediting period

Project developers are eligible to register GHG reductions with the Reserve according to this protocol for a period of ten years. The first reduction year commences after the biogas control system becomes operational. As described above, a system is operating if it is capturing and combusting methane gas from the treatment of the project developer's livestock waste.

Non-Climate Action Reserve reporting

The Reserve requests that project developers only register reductions from manure management GHG reduction projects with one registry. However, under a voluntary system, enforcement authority is limited. Therefore, if a project developer participates in this program it is their responsibility to transparently disclose the registration of all reductions associated with the project activity that occur outside of the Reserve.

[33] General Reporting Protocol, IV.14.7. http://www.climateregistry.org/PROTOCOLS/GRCP/

References

American Society of Agricultural Engineers, Standard: ASAE D384.2 (2005).

Intergovernmental Panel on Climate Change, Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (2001).

Intergovernmental Panel on Climate Change, IPCC Guidelines for National Greenhouse Gas Inventories, Chapter 10: Emissions from Livestock and Manure Management (2006).

Intergovernmental Panel on Climate Change, IPCC Guidelines for National Greenhouse Gas Inventories, Chapter 11: N20 Emissions from Managed Soils, and CO2 Emissions from Lime and Urea Application (2006).

Regional Greenhouse Gas Initiative, Draft Model Rule (January 2007).

Mangino, J., Bartram, D. and Brazy, A. Development of a methane conversion factor to estimate emissions from animal waste lagoons. Presented at U.S. EPA's 17th Annual Emission Inventory Conference, Atlanta GA, April 16-18, 2001.

United Nations Framework Convention on Climate Change (UNFCCC), Revisions to the Approved Consolidated Baseline Methodology ACM0010, “Consolidated baseline methodology for greenhouse gas emission reductions from manure management systems,” Clean Development Mechanism, Version 02, Sectoral Scopes 13 and 15 (2006).

U.S. Department, of Agriculture Natural Resources Conservation Service, Conservation Practice Standard, Anaerobic Digester—Ambient Temperature, No. 365

U.S. Department of Agriculture Natural Resources Conservation Service, Conservation Practice Standard, Anaerobic Digester—Controlled Temperature, No. 366

U.S. Department of Agriculture Natural Resources Conservation Service, Conservation Practice Standard, Waste Storage Facility, No. 313

U.S. Department of Agriculture Natural Resources Conservation Service, Conservation Practice Standard, Waste Treatment Lagoon, No. 359

U.S. Department of Energy 1605(b) Technical Guidelines for Voluntary Reporting of Greenhouse Gas Program

U.S. Environmental Protection Agency, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005, EPA-430-R-07-002 (April 2007).

U.S. Environmental Protection Agency - Climate Leaders, Draft Manure Offset Protocol, (October 2006).

Association of State Energy Research and Technology Transfer Institutions (ASERTTI), U.S. Environmental Protection Agency AgStar Program, and U.S. Department of Agriculture Rural Development, Protocol for Quantifying and Reporting the Performance of Anaerobic Digestion Systems for Livestock Manures (January 2007).

World Resource Institute and World Business Counsel for Sustainable Development, Greenhouse Gas Protocol for Project Accounting (November 2005).

Appendix A – Associated Environmental Impacts

Manure management projects have many documented environmental benefits, including air emissions reductions, water quality protection, and electricity generation. These benefits are the result of practices and technologies that are well managed, well implemented, and well designed. However, in cases where practices or technologies are poorly or improperly designed, implemented, and/or managed, local air and water quality could be compromised.

With regard to air quality, there are a number of factors that must be considered and addressed to realize the environmental benefits of a biogas project and reduce or avoid potential negative impacts. Uncontrolled emissions from combustion of biogas may contain between 200 to 300 ppm NOx. The anaerobic treatment process creates intermediates such as ammonia, hydrogen sulfide, orthophosphates, and various salts, all of which must be properly controlled or captured. In addition, atmospheric releases at locations off-site where bio-gas is shipped may negate or decrease the benefit of emissions controls on-site. Thus, while devices such as Selective Catalyst Reduction (SCR) units can reduce NOx emissions and proper treatment system operation can control intermediates, improper design or operation may lead to violations of federal, state, and local air quality regulations as well as release of toxic air contaminants.

With regard to water quality, it is critical that project developers and managers ensure digester integrity and fully consider and address post-digestion management of the effluent in order to avoid contamination of local waterways and groundwater resources. Catastrophic digester failures; leakage from pipework and tanks; and lack of containment in waste storage areas are all examples of potential problems. Further, application of improperly treated digestate and/or improper application timing or rates of digestate to agricultural land may lead to increased nitrogen oxide emissions, soil contamination, and/or nutrient leaching, thus negating or reducing benefits of the project overall.

Project developers must not only follow the protocol to register GHG reductions with the Reserve, they must also comply with all local, state, and national air and water quality regulations. Projects must be designed and implemented to mitigate potential releases of pollutants such as those described, and project managers must acquire the appropriate local permits prior to installation to prevent violation of the law.

The Reserve agrees that GHG emission reduction projects should not undermine air and water quality efforts and will work with stakeholders to establish initiatives to meet both climate-related and localized environmental objectives.

Appendix B – Emission Factor Tables

Table B.1: Manure management system components

System	Definition
Pasture/Range/ Paddock	The manure from pasture and range grazing animals is allowed to lie as deposited, and is not managed.
Daily spread	Manure is routinely removed from a confinement facility and is applied to cropland or pasture within 24 hours of excretion.
Solid storage	The storage of manure, typically for a period of several months, in unconfined piles or stacks. Manure is able to be stacked due to the presence of a sufficient amount of bedding material or loss of moisture by evaporation.
Dry lot	A paved or unpaved open confinement area without any significant vegetative cover where accumulating manure may be removed periodically.
Liquid/Slurry	Manure is stored as excreted or with some minimal addition of water in either tanks or earthen ponds outside the animal housing, usually for periods less than one year.
Uncovered anaerobic lagoon	A type of liquid storage system designed and operated to combine waste stabilization and storage. Lagoon supernatant is usually used to remove manure from the associated confinement facilities to the lagoon. Anaerobic lagoons are designed with varying lengths of storage (up to a year or greater), depending on the climate region, the volatile solids loading rate, and other operational factors. The water from the lagoon may be recycled as flush water or used to irrigate and fertilize fields.
Pit storage below animal confinements	Collection and storage of manure usually with little or no added water typically below a slatted floor in an enclosed animal confinement facility, usually for periods less than one year.
Anaerobic digester	Animal excreta with or without straw are collected and anaerobically digested in a large containment vessel or covered lagoon. Digesters are designed and operated for waste stabilization by the microbial reduction of complex organic compounds to CO2 and CH4, which is captured and flared or used as a fuel.
Burned for fuel	The dung and urine are excreted on fields. The sun dried dung cakes are burned for fuel.
Cattle and Swine deep bedding	As manure accumulates, bedding is continually added to absorb moisture over a production cycle and possibly for as long as 6 to 12 months. This manure management system also is known as a bedded pack manure management system and may be combined with a dry lot or pasture.
Composting – in-vessel*	Composting, typically in an enclosed channel, with forced aeration and continuous mixing.
Composting – Static pile*	Composting in piles with forced aeration but no mixing.
Composting – Intensive windrow*	Composting in windrows with regular (at least daily) turning for mixing and aeration.
Composting – Passive windrow*	Composting in windrows with infrequent turning for mixing and aeration.
Aerobic treatment	The biological oxidation of manure collected as a liquid with either forced or natural aeration. Natural aeration is limited to aerobic and facultative ponds and wetland systems and is due primarily to photosynthesis. Hence, these systems typically become anoxic during periods without sunlight.

*Composting is the biological oxidation of a solid waste including manure usually with bedding or another organic carbon source typically at thermophilic temperatures produced by microbial heat production.

Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Chapter 10: Emissions from Livestock and Manure Management, Table 10.18: Definitions of Manure Management Systems, p. 10.49.

Table B.2: Livestock categories

Lactating dairy cows
Non-milking dairy cows
Heifers
Calves
Bulls (pasture/grazing)
Calves (pasture/grazing)
Heifers (pasture/grazing)
Dairy cows (pasture/grazing)
Nursery swine
Grow/finish swine
Breeding swine

Table B.3: Volatile Solids and Maximum Methane Potential by Livestock Category

Livestock category (*L*)	VS_L (kg/day/1,000 kg mass)	$B_{o,L}$ [b] (m^3 CH_4/kg VS added)
Lactating dairy cows	Use equation 2a	0.35*
Non-milking dairy cows	9.2[a]	0.24**
Heifers	See Appendix B, Table 4	0.17
Calves	Project developer judgment	Project developer judgment
Bulls (pasture/grazing)	6.04[b]	0.17
Calves (pasture/grazing)	6.41[b]	0.17
Heifers (pasture/grazing)	See Appendix B, Table 4	0.17
Dairy cows (pasture/grazing)	See Appendix B, Table 4	0.17
Nursery swine	8.89[b]	0.48
Grow/finish swine	5.36[b]	0.48
Breeding swine	2.71[b]	0.35

* Value for Dairy lactating cows assumes a low roughage (high energy) diet.
** Value for Dairy dry cows assumes a high roughage (low energy) diet.

Sources:

a. American Society of Agricultural Engineers (ASAE) Standards 2005, ASAE D384.2, Table 1b, Section 3: All other livestock and poultry, p.2.

b. Environmental Protection Agency (EPA)-Climate Leaders, Draft Manure Offset Protocol, October 2006, Table IIa: Animal Waste Characteristics (VS, Bo, and N_{ex} rates), p. 18.

Table B.4: Volatile Solids for Heifers, Heifers-pasture/grazing and Cows-pasture/grazing by State

State	VS Heifer (kg/day per 1,000 kg mass)	VS Heifer -pasture/grazing (kg/day per 1,000 kg mass)	VS Cows-pasture/grazing (kg/day per 1,000 kg mass)
Alabama	6.81	7.24	6.74
Alaska	6.81	9.52	8.71
Arizona	6.81	9.57	8.71
Arkansas	7.56	7.23	6.72
California	6.81	7.12	6.57
Colorado	6.81	6.75	6.19
Connecticut	6.13	7.14	6.62
Delaware	6.13	7.26	6.62
Florida	6.81	7.21	6.74
Georgia	6.81	7.24	6.74
Hawaii	6.81	9.56	8.71
Idaho	6.81	9.68	8.71
Illinois	6.81	7.22	6.63
Indiana	6.81	7.20	6.63
Iowa	6.81	7.25	6.63
Kansas	6.81	6.75	6.19
Kentucky	6.81	7.28	6.74
Louisiana	7.56	7.19	6.72
Maine	6.13	7.11	6.62
Maryland	6.13	7.17	6.62
Massachusetts	6.13	7.11	6.62
Michigan	6.81	7.20	6.63
Minnesota	6.81	7.21	6.63
Mississippi	6.81	7.23	6.74
Missouri	6.81	7.17	6.63
Montana	6.81	6.61	6.19
Nebraska	6.81	6.75	6.19
Nevada	6.81	9.60	8.71
New Hampshire	6.13	7.11	6.62
New Jersey	6.13	7.15	6.62
New Mexico	6.81	9.64	8.71
New York	6.13	7.19	6.62
North Carolina	6.81	7.23	6.74
North Dakota	6.81	6.69	6.19
Ohio	6.81	7.18	6.63
Oklahoma	7.56	7.30	6.72
Oregon	6.81	9.62	8.71
Pennsylvania	6.13	7.18	6.62
Rhode Island	6.13	7.11	6.62
South Carolina	6.81	7.25	6.74
South Dakota	6.81	6.70	6.19
Tennessee	6.81	7.24	6.74
Texas	7.56	7.32	6.72
Utah	6.81	9.62	8.71
Vermont	6.13	7.15	6.62
Virginia	6.81	7.27	6.74
Washington	6.81	9.69	8.71
West Virginia	6.13	7.13	6.62
Wisconsin	6.81	7.17	6.63
Wyoming	6.81	6.66	6.19

Source: Environmental Protection Agency (EPA)-Climate Leaders, Draft Manure Offset Protocol, October 2006, Table IIb: Volatile Solids (VS) Production for Cattle Subcategories by State (2004), p. 19.

Table B.5: IPCC 2006 Methane Conversion Factors by Manure Management System Component/Methane Source ‘S’ [34]

MCF VALUES BY TEMPERATURE FOR MANURE MANAGEMENT SYSTEMS

System[a]		MCFs by average annual temperature (°C)																			Source and comments
		Cool					Temperate											Warm			
		≤ 10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	≥ 28	
Pasture/Range/Paddock		1.0%					1.5%											2.0%			Judgement of IPCC Expert Group in combination with Hashimoto and Steed (1994).
Daily spread		0.1%					0.5%											1.0%			Hashimoto and Steed (1993).
Solid storage		2.0%					4.0%											5.0%			Judgement of IPCC Expert Group in combination with Amon et al. (2001), which shows emissions of approximately 2% in winter and 4% in summer. Warm climate is based on judgement of IPCC Expert Group and Amon *et al*. (1998).
Dry lot		1.0%					1.5%											2.0%			Judgement of IPCC Expert Group in combination with Hashimoto and Steed (1994).
Liquid/Slurry	With natural crust cover	10%	11%	13%	14%	15%	17%	18%	20%	22%	24%	26%	29%	31%	34%	37%	41%	44%	48%	50%	Judgement of IPCC Expert Group in combination with Mangino *et al*. (2001) and Sommer (2000). The estimated reduction due to the crust cover (40%) is an annual average value based on a limited data set and can be highly variable dependent on temperature, rainfall, and composition. When slurry tanks are used as fed-batch storage/digesters, MCF should be calculated according to Formula 1.
	Without natural crust cover	17%	19%	20%	22%	25%	27%	29%	32%	35%	39%	42%	46%	50%	55%	60%	65%	71%	78%	80%	Judgement of IPCC Expert Group in combination with Mangino *et al*. (2001). When slurry tanks are used as fed-batch storage/digesters, MCF should be calculated according to Formula 1.

[34] From 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Chapter 10: Emissions from Livestock and Manure Management, Table 10.17

MCF VALUES BY TEMPERATURE FOR MANURE MANAGEMENT SYSTEMS																				
System[a]		**MCFs by average annual temperature (°C)**																		**Source and comments**
		Cool					**Temperate**											**Warm**		
		≤ 10	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**≥ 28**	
Uncovered anaerobic lagoon		66%	68%	70%	71%	73%	74%	75%	76%	77%	77%	78%	78%	78%	79%	79%	79%	79%	80%	80%	Judgement of IPCC Expert Group in combination with Mangino *et al*. (2001). Uncovered lagoon MCFs vary based on several factors, including temperature, retention time, and loss of volatile solids from the system (through removal of lagoon effluent and/or solids).
Pit storage below animal confinements	< 1 month	3%					3%											3%			Judgement of IPCC Expert Group in combination with Moller *et a*l. (2004) and Zeeman (1994). Note that the ambient temperature, not the stable temperature is to be used for determining the climatic conditions. When pits used as fed-batch storage/digesters, MCF should be calculated according to Formula 1.
	> 1 month	17%	19%	20%	22%	25%	27%	29%	32%	35%	39%	42%	46%	50%	55%	60%	65%	71%	78%	80%	Judgement of IPCC Expert Group in combination with Mangino *et a*l. (2001). Note that the ambient temperature, not the stable temperature is to be used for determining the climatic conditions. When pits used as fed-batch storage/digesters, MCF should be calculated according to Formula 1.

MCF VALUES BY TEMPERATURE FOR MANURE MANAGEMENT SYSTEMS																				
System[a]		**MCFs by average annual temperature (°C)**																		**Source and comments**
		Cool					**Temperate**										**Warm**			
		≤ 10	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**≥ 28**	
Anaerobic digester		0-100%					0-100%										0-100%			Should be subdivided in different categories, considering amount of recovery of the biogas, flaring of the biogas and storage after digestion. Calculation with Formula 1.
Burned for fuel		10%					10%										10%			Judgement of IPCC Expert Group in combination with Safley *et al*. (1992).
Cattle and Swine deep bedding	< 1 month	3%					3%										30%			Judgement of IPCC Expert Group in combination with Moller *et* al. (2004). Expect emissions to be similar, and possibly greater, than pit storage, depending on organic content and moisture content.
Cattle and Swine deep bedding (cont.)	> 1 month	17%	19%	20%	22%	25%	27%	29%	32%	35%	39%	42%	46%	50%	55%	60%	65%	71%	78%	90%	Judgement of IPCC Expert Group in combination with Mangino *et al*. (2001).
Composting - In-vessel[b]		0.5%					0.5%										0.5%			Judgement of IPCC Expert Group and Amon *et al*. (1998). MCFs are less than half of solid storage. Not temperature dependant.
Composting - Static pile[b]		0.5%					0.5%										0.5%			Judgement of IPCC Expert Group and Amon *et al*. (1998). MCFs are less than half of solid storage. Not temperature dependant.
Composting - Intensive windrow[b]		0.5%					1.0%										1.5%			Judgement of IPCC Expert Group and Amon *et al*. (1998). MCFs are slightly less than solid storage. Less temperature dependant.
Composting – Passive windrow[b]		0.5%					1.0%										1.5%			Judgement of IPCC Expert Group and Amon *et al*. (1998). MCFs are slightly less than solid storage. Less temperature dependant.
Aerobic treatment		0%					0%										0%			MCFs are near zero. Aerobic treatment can result in the accumulation of sludge which may be treated in other systems. Sludge requires removal and has large VS values. It is important to identify the next management process for the sludge and estimate the emissions from that management process if significant.

a Definitions for manure management systems are provided in Table 1.
b Composting is the biological oxidation of a solid waste including manure usually with bedding or another organic carbon source typically at thermophilic temperatures produced by microbial heat production.

Appendix C – Summary of the Performance Standard Paper

The analysis to establish a Performance Standard for the Manure Management Project Protocol was undertaken by Science Applications International Corporation (SAIC) and independent consultant Kathryn Bickel. It took place at the end of 2006. The analysis culminated in a paper that provided a Performance Standard recommendation to support the Reserve's protocol development process, which the Reserve has incorporated into the protocol's eligibility rules (see Section III).[35]

The purpose of a Performance Standard is to establish a threshold that is significantly better than average greenhouse gas (GHG) production for a specified service, which, if met or exceeded by a project developer, satisfies the criterion of "additionality". The Reserve's project protocol focuses on the following direct emission reduction activity: capturing and combusting methane from managing livestock manure. Therefore, in this case the methane emissions correspond to GHG production, and manure treatment/storage correspond to the specified service.

The analysis to establish the Performance Standard evaluated U.S. and California-specific data on dairy and swine manure management systems. Ultimately, it recommended a practice-based/technology-specific GHG emissions Performance Standard – i.e., the installation of a manure digester (or biogas control system, more generally). The paper had the following sections:

- The livestock industry in the U.S. and California,
- Livestock manure management practices,
- GHG emissions from livestock manure management,
- Data on livestock manure management practices in the U.S. and California,
- Current and anticipated regulations in California impacting manure management practices,
- Recommendation for a performance threshold for livestock operations, and
- Considerations for baseline determinations.

Overview of data collection

Conditions for methane generation exist under manure treatment and storage, namely anaerobic lagoons and/or storage ponds. The distribution of livestock across different sized operations can be an important criterion when developing a livestock manure management Performance Standard. There is a general relationship between manure management practices and operation size, where larger operations (in terms of livestock numbers) tend to use manure management systems that treat and store waste in liquid form (i.e., flush or scrape/slurry systems), particularly in dairy and swine operations.[36]

---

[35] The full Performance Standard report is available on the Registry's website: http://www.climateregistry.org/PROTOCOLS/PIP/1/

[36] U.S. Inventory of Greenhouse Gas Emissions and Sinks: 1990-2004 (and earlier editions), US Environmental Protection Agency, Report # 430-R-06-002, April 2006. Available at: http://www.epa.gov/climatechange/emissions/usinventoryreport.html

U.S. and California livestock population data. The report presents data on livestock type and population in the U.S. It also describes the livestock industry in California in relation to U.S. operations. Table C.1 shows that California raises 16.5% of all dairy cows in the US on only 3% of US dairy operations, indicating that California has relatively few but substantially sized diary operations.

Table C.1: Livestock Population Data for the U.S. and California, 2002

	US		California			
	# Farms	# Animals	# Farms	# Animals	% of US Farms	% of US Animals
Dairy	91,989	17,013,361	2,793	2,806,357	3.0%	16.5%
Beef	796,436	34,431,060	12,497	879,582	1.6%	2.6%
Hogs	78,895	60,405,103	1,521	163,465	1.9%	0.3%

Source: U.S. Department of Agriculture National Agricultural Statistics Service (2004)

U.S. data on manure management practices. A data source to assess national-level manure management practices comes from the Draft EPA Climate Leaders Manure Management Protocol.[37] It uses data on farm distribution and manure management systems from the Manure Management portion of the Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2004, uses data on the number of farms by farm size and geographic location from the 2002 Census of Agriculture.

Information compiled for the EPA's U.S. GHG Inventory also provided the Climate Leaders protocol with a breakdown of the assumed predominant manure management system in use for dairy and swine operations. Table C.2 and C.3 show data compiled for the systems in place in 2006.

Table C.2: Dairy and Swine Operations in the U.S. by Manure Management System

Animal	Number of Operations by Manure Management System						
	P/R/P	**Anaerobic Digester**	**Lagoon**	**Liquid/ Slurry**	**Solid Storage**	**Deep Pit**	**Total**
Dairy	72,487	62	4,453	4,345	9,494	1,147	91,989
Swine	53,230	18	6,571	6,303	1,129	11,643	78,894

Source: U.S. EPA - Climate Leaders, Draft Manure Offset Protocol, Table I.A

[37] http://www.epa.gov/climateleaders/docs/ClimateLeaders_DraftManureOffsetProtocol.pdf

Table C.3. Dairy and Swine Operations by Size and Manure Management System

Animal	Number of Operations by Farm Size and Manure Management System							
	Farm Size	**P/R/P**	**Anaerobic Digester**	**Lagoon**	**Liquid/ Slurry**	**Solid Storage**	**Deep Pit**	**Total**
Dairy	≥500 head	320	48	1,614	675	245	-	2,902
	200-499	3,213	9	617	652	54	-	4,546
	1-199	6,8954	5	2,223	3,017	9,195	1,147	84,541
Swine	≥2000 head	-	14	2,581	1,084	297	2,774	6,749
	200-2000	-	3	3,990	5,219	832	8,869	18,913
	1-199	53,230	1	-	-	-	-	53,231

Source: U.S. 2002 Census of Agriculture

The EPA Climate Leaders protocol focuses on the prevalence of anaerobic digesters for determining their performance threshold. Data on the implementation of anaerobic digesters at animal operations was taken from the Interim Draft Winter 2006 AgSTAR Digest. Of 91,988 dairy and 78,894 swine farm operations in the United States, a total of 80 anaerobic digesters are currently in operation: 62 (0.07%) for dairy manure and 18 (0.02%) for swine manure.

Data were also disaggregated in the Climate Leaders protocol to determine whether digester installation was a common practice in any animal production operation size range. As was shown in Table C.3, even at large animal production operations, very few digester systems are in place. At dairy farms with ≥500 head, only 1.7% of manure management systems include digesters, and of swine farms with >2000 head, only 0.2% have digesters.

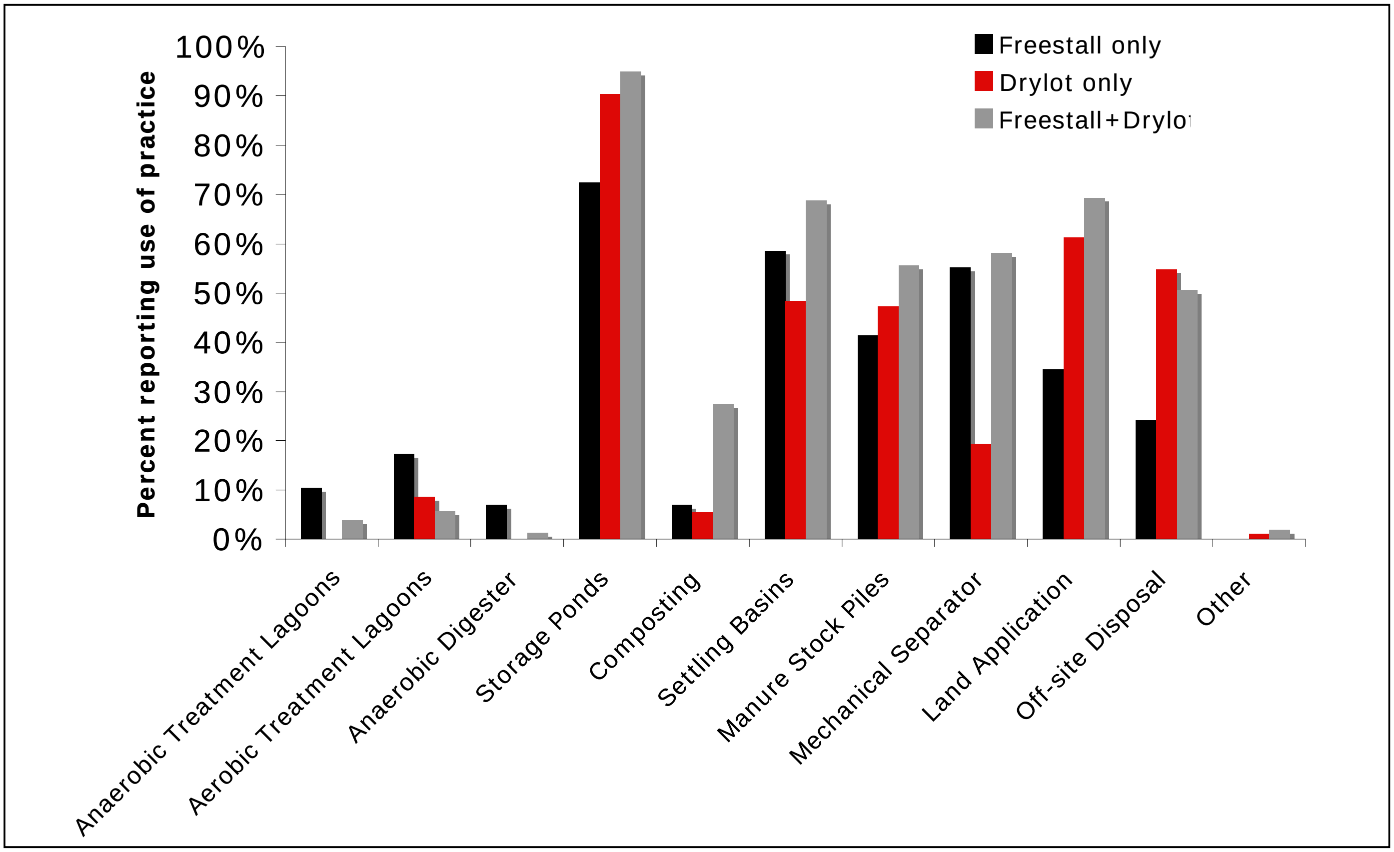
Regarding swine operations, there are few large farms in California. As was noted previously, most swine in California (76%) are raised on only twelve operations with over 1,000 head each, while most farms with swine in California are very small and have less than 24 head. The majority of swine are then managed on large operations where the manure is very likely transported and stored in liquid form.

California data on manure management practices. The most comprehensive data source for California dairies comes from permit application data submitted to San Joaquin Valley (SJV) and South Coast (SC) Air Pollution Control Districts to meet air quality permit requirements. The data were provided by Applied GeoSolutions, which maintains a database of manure management practices from the permits.

The permit database includes information from 293 dairies housing approximately 1.2 million cows, which covers about 57% of California dairies with herds greater than 1,000 head. Most dairies (282) are in the San Joaquin Valley and the rest are in the South Coast.

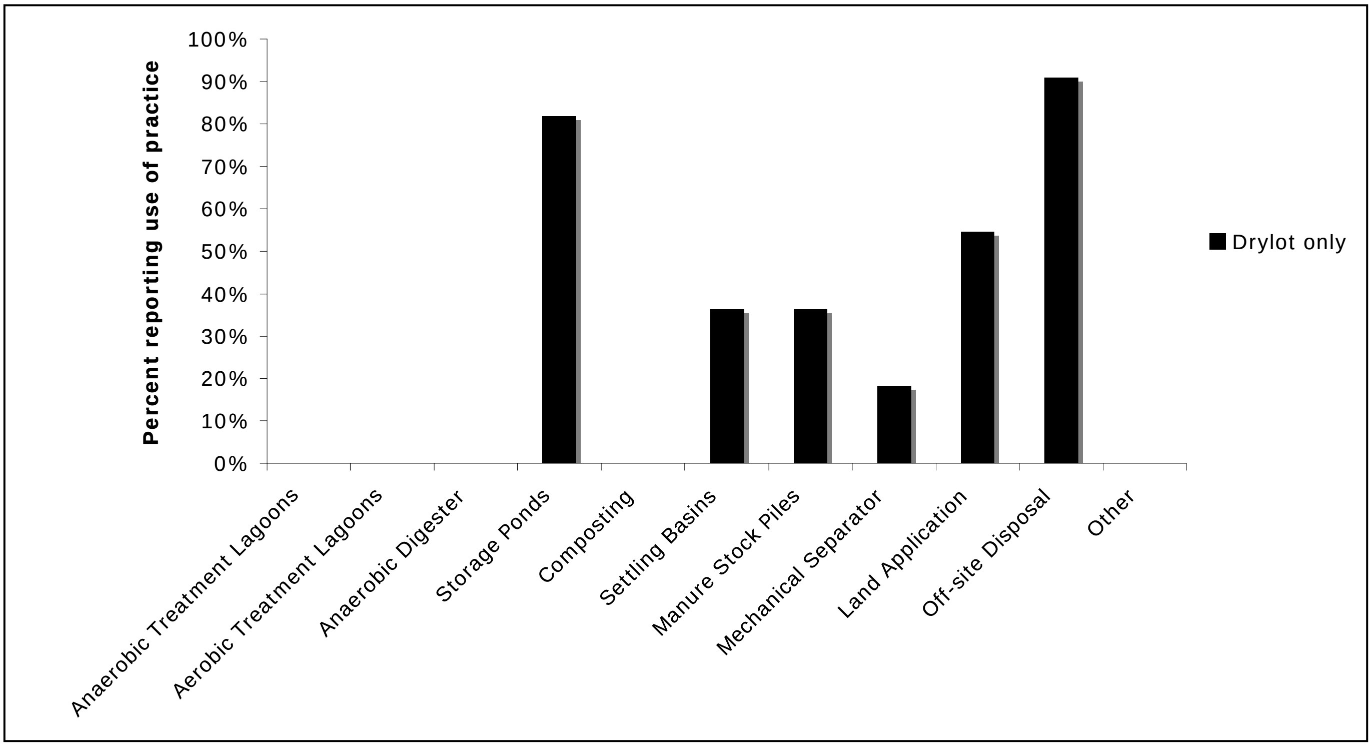
Most permits from operators in the SJV report the use both freestall and drylot configurations (56%), a third report drylot only (33%), and a few report freestall only.[38] A single operator could choose more than one practice. The figures below show the percent of SJV and SC dairies, by dairy type, reporting the use of specific handling practices.

Figure C.1: Manure Handling Practices at SJV Dairies



[38] Operators provided additional information on specific manure handling practices in the permit data.

Figure C.2: Manure Handling Practices at SC Dairies



Based on the information contained in the San Joaquin Valley and South Coast permit database the report makes following key findings.

Liquid components:

- Most (91% of total) dairies report using storage ponds (fewer for freestall only operations because they are reporting their liquid storage in other categories, i.e., aerobic and anaerobic lagoons)
- Few (3% of total) report using anaerobic treatment lagoons (most are on freestall only operations)
- Few (8% of total) report using aerobic[39] treatment lagoons (most are on freestall only operations)
- Very few dairies (1% of total) report using anaerobic digesters (4 total, 2 on freestall only and 2 on freestall+drylot)

Dry components:

- Less than 10% of freestall only and drylot dairies, and less than 30% of freestall+drylot dairies use composting[40] (18% overall)
- Use of manure stockpiles ranges from ~40 to 55% (51% overall)
- 50-60% of freestall dairies (only and +drylot) use mechanical separation, compared to ~20% of drylots (45% overall)
- 50-70% use settling basins (more freestall and than drylots) (61% overall)

[39] These are believed to be "red" or phototropic lagoons used for odor control and not true aerobic lagoons according to personal communication with Paul Sousa at the Western United Dairymen.
[40] Composting is predominantly, if not entirely, windrow composting as per Paul Sousa - WUD

Current digester use in California. The report provides information from the EPA AgStar program, which offers technical support to livestock operators for installation and operation of anaerobic digesters. The Interim Draft Winter 2006 AgSTAR Digest states that there are 18 anaerobic digesters operating in California; only one is on a swine operation and the rest are on dairies. Eleven of the 17 dairy digesters are on operations with greater than 1,000 head. The uptake of digesters in California is less than 1% (0.6%) of the State's 2,793 dairies. And the 11 digesters operating on large dairies (>1000 dairy cows) calculates to 2.1% of this group (California has 517 dairies with more than 1000 cows – from the full report, Table 3, 'California Data on Livestock Operations, by Farm Size').

Additionally, the report considered the California Energy Commission's (CEC) 2006 Energy Action Plan, which states that a total of 14 projects have been approved for grants through 2005 totaling $5,792,370 under the Dairy Power Production Program (as of the end of 2006). It is unclear how many of these 14 digesters are currently operating and whether they are also captured in the AgStar database. Geographic information on the digester locations is available from a November 2004 map prepared by the CEC[41]. It shows 14 digester operations that convert methane to energy in the following air basins:

- SJV APCD – 8 digesters
- SCAQMD – 2 digesters
- BAAQMD – 1 digester
- South Central Coast (San Luis Obispo) – 1 digester
- San Diego Air Basin – 1 digester
- Mojave Desert Air Basin – 1 digester

Evaluation of regulatory requirements. The report evaluated recently passed regulations that affect the management of manure at dairies and at other livestock operations. The analysis included the San Joaquin Valley Air Pollution Control District's Rule 4570 adopted on June 15, 2006, which requires all large confined animal feeding operations (CAFs) to apply for permits and adopt various practices that will reduce volatile organic compounds, ammonia, and hydrogen sulfide emissions. The Sacramento Air Quality Management District adopted an almost identical rule – Rule 496 adopted August 24, 2006.

The report states that although the solid waste and liquid waste mitigation measures noted in Rule 4570 and Rule 496 could impact methane emissions, the rules are structured to allow large CAFs to select from a variety of control options – so there is no specific requirement for digesters to be installed. A summary of compliance options for Rule 4570 and Rule 496.

1. Non-permitted dairy below large CAF cutoff – drylot (continue current practice)
2. Non-permitted dairy below large CAF cutoff – freestall scrape (continue current practice)
3. Non-permitted dairy below large CAF cutoff – freestall flush (continue current practice)

[41] http://www.energy.ca.gov/pier/renewable/biomass/pier_biogas_projects_maps/index.html

4. Non-permitted swine farm below large CAF cutoff – continue current practice
5. Large CAF dairy – drylot – (assume pond converted to anaerobic lagoon or mechanical separator installed to comply with Rule 4570/496)
6. Large CAF dairy – freestall scrape (assume pond converted to anaerobic lagoon or mechanical separator installed to comply with Rule 4570/496)
7. Large CAF dairy – freestall flush (assume pond converted to anaerobic lagoon or mechanical separator installed to comply with Rule 4570/496)
8. Large CAF swine farm - assume pond converted to anaerobic lagoon or mechanical separator installed to comply with Rule 4570/496
9. New or modified large CAF– all categories (assume installation of anaerobic lagoon unless new BACT determination is made requiring digesters).

Performance Standard Recommendation

The report recommends that a Performance Standard apply to the control of methane emissions from dairy and swine livestock operations in the U.S. and California. In particular, the Performance Standard should be a technology-specific threshold that dairy or swine operators would meet. The threshold should be the installation of a biogas control system (anaerobic digester).

California serves as a good proxy for the U.S. regarding the level of digester use and the likelihood of its use as common practice. The data shows that California livestock operations (dairy, in particular) manage waste in a manner that is very suitable for digesters – i.e., liquid-based system. Yet even in these favorable conditions digester are found on less than 1% of the dairies. The report concludes that if a dairy operator chooses to install a digester than the farmer would be managing waste in the 99th percentile. This constitutes above and beyond common practice.

Moreover, the main barrier inhibiting the installation and use of digesters is cost. EPA's AgStar program has developed cost curves indicating that for a 4000 cow dairy, the cost of a covered lagoon digester is approximately $1 million, and $1.2 million for a plug flow digester. AgStar estimated digester costs are considerably less for a 1000 cow dairy - approximately $250,000 for the covered lagoon and $450,000 for the plug flow digester – but the generated methane volumes are proportionately less. A 2005 CEC study42 showed that the cost of biogas recovered (after considering amortized capital costs) from 14 plug flow digesters in the U.S. averaged $10.05 per cubic foot. The costs of recovered biogas were even higher for complete mix digesters – over $11 per cubic foot for 3 systems in the U.S. and over $16 per cubic foot for system in Denmark. These indicate non-commercial rates for gas recovered and that significant subsidies and/or incentives are needed to encourage additional digester installations.

[42] Commonwealth Energy Biogas/PV Mini-Grid Renewable Resources Program; "Making Renewables Part of an Affordable and Diverse Electric System in California;" Contract No. 500-00-036; Digester Comparison Study.

Appendix D – Information for Taking Entity-Level GHG Emissions Inventories

This guidance to take an entity-level greenhouse gas (GHG) emissions inventory for livestock operations is an appendix to the California Registry's General Reporting Protocol (GRP). Livestock operators that register reductions with Reserve according to the Manure Management Project Reporting Protocol are not required to also report entity-level emissions.

The California Registry's GRP provides principles, procedures, and methodologies to guide entities in accounting for and reporting entity-level GHG emissions to the Reserve. It is designed to support the complete, transparent, accurate, and consistent reporting of an organization's absolute GHG emissions inventory. To register entity-level emissions with the Reserve, livestock operators follow the reporting procedures in this document and the GRP.

Reporting guidance coverage in the GRP and this document

The GRP describes the California Registry's basic registration and reporting process and explains the parameters that determine which sources of emissions must be included in a company's inventory, based on their location and the reporter's organizational structure and operations. It provides general guidance for reporting all basic types of direct and indirect GHG emissions and also serves as the key resource for instructing reporters in completing and submitting their emission report (e.g. determining *de minimis* emissions, establishing and updating a GHG emission baseline, preparing and submitting an annual report using CARROT and understanding verification).

Under entity-level reporting, the livestock operator reports GHG emissions from significant mobile and stationary fossil fuel combustion sources, process-related emission sources, fugitive emission sources, fugitive sources, and indirect sources like electricity consumption. The California Registry strongly encourages the reporting of GHG emissions information at the facility- or source-level as part of the entity-level report. Although facility-level reporting may require more data collection and organization work, it will provide a more detailed and comprehensive picture of the company's emissions profile and could reduce verification costs.

Box E.1: Reserve Reporting Protocols for the Livestock Sector

General Reporting Protocol Guidance

Reporting parameters
- Geographic boundaries
- Organizational boundaries
- Operational boundaries
- Using CARROT
- Establishing and updating a baseline

Quantifying GHG emissions
- Mobile sources
- Stationary combustion sources
- Process
- Fugitive
- Purchased and consumed electricity
- Purchased and consumed steam/heat

Completing and Submitting Report
- *De Minimis* Emissions
- Understanding CARROT and certification

This Protocol

Process N_2O from manure management and the application of manure and fertilizer to fields

Process CH_4 from enteric fermentation

This Protocol

Fugitive CO_2 from soils

Process-related nitrous oxide emissions. The Reserve provides the following guidance for assessing process-related nitrous oxide emissions:

1. Nitrous oxide emissions from manure management and the application of manure to fields – livestock operators should follow the guidance in Appendix D, project nitrous oxide emissions. It refers to ACM0010.
2. Nitrous oxide emissions from the application of – livestock operators should follow the guidance in the DOE 1605(b) Technical Guidelines, section 1.H.4.2.3 N2O from Agricultural Soils.
3. Methane emissions from enteric fermentation – livestock operators should follow the guidance in the DOE 1605(b) Technical Guidelines, section 1.H.4.1.2 Enteric Fermentation

Fugitive carbon dioxide emissions. The Reserve provides the following guidance for assessing fugitive carbon dioxide emissions from soils:

- Livestock operators should follow the guidance in the DOE 1605(b) Technical Guidelines for Voluntary Reporting of Greenhouse Gas Program Chapter 1, Emission Inventories, Part H Appendix: Estimating Carbon Fluxes from Agricultural Lands Using the CarbOn Management Evaluation Tool for Voluntary Reporting (COMET-VR©)