CLIMATE LEADERS GREENHOUSE GAS INVENTORY PROTOCOL OFFSET PROJECT METHODOLOGY

for

Project Type: Managing Manure with Biogas Recovery Systems

Climate Protection Partnerships Division/Climate Change Division
Office of Atmospheric Programs
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Climate Leaders *is an EPA industry-government partnership that works with companies to develop comprehensive climate change strategies. Partner companies commit to reducing their impact on the global environment by setting aggressive greenhouse gas reduction goals and annually reporting their progress to EPA.*

Introduction

An important objective of the Climate Leaders program is to focus corporate attention on achieving cost-effective greenhouse gas (GHG) reductions within the boundary of the organization (i.e., internal projects and reductions). Partners may also use reductions and/or removals which occur outside their organizational boundary (i.e., external reductions or "offsets") to help them achieve their goals. To ensure that the GHG emission reductions from offsets are credible, Partners must ensure that the reductions meet four key accounting principles:

- ***Real:*** The quantified GHG reductions must represent actual emission reductions that have already occurred.
- ***Additional:*** The GHG reductions must be surplus to regulation and beyond what would have happened in the absence of the project or in a business-as-usual scenario based on a performance standard methodology.
- ***Permanent:*** The GHG reductions must be permanent or have guarantees to ensure that any losses are replaced in the future.
- ***Verifiable:*** The GHG reductions must result from projects whose performance can be readily and accurately quantified, monitored and verified.

This paper provides a performance standard (accounting methodology) for greenhouse gas (GHG) offset projects that introduce methane (CH_4) collection and combustion (biogas recovery system) into a dairy or swine manure management system at an existing farm. The accounting methodology presented in this paper addresses the eligibility of manure management methane collection and combustion projects as greenhouse gas offset projects and provides measurement and monitoring guidance. Program design issues (e.g., project lifetime, project start date) are not within the scope of this guidance and are addressed in the Climate Leaders offset program overview document: Using Offsets to Help Climate Leaders Achieve Their GHG Reduction Goals.[1]

A common method for reducing GHG emissions from manure management systems is the replacement of a conventional anaerobic manure management technology (e.g., lagoons, liquid/slurry systems) with a digester system that collects and combusts manure gas. At some digester systems, gas is combusted by flaring; at others, gas is combusted for energy or heat production and use.

For the purposes of the performance standard described in this paper, any energy or heat producing technology should be considered solely as a combustion device. The methodology

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[1] Please visit http://www.epa.gov/climateleaders/resources/optional-module.html to download the overview document.

does not apply to quantification of emission reductions from the use of manure gas to generate electricity or heat energy, resulting in the displacement of GHG emissions from fossil fuel combustion. A separate methodological paper will present the methodology to be used for quantifying the GHG emissions avoided by a fuel substitution end use project.

Description of Project Type

In the United States, more than two billion animals are housed on farms to produce meat, milk, and other products. These animal production operations include a variety of management systems, such as pastures, rangeland, totally or partially enclosed barns or houses, and open lots. Manure management practices vary, and are typically based on the type and size of the farm relative to land availability for nutrient uptake and management.

Manure management can result in CH_4 and nitrous oxide (N_2O) emissions, depending on the systems in place. In the United States, manure management systems account for 7 percent of total anthropogenic CH_4 emissions and 4 percent of N_2O emissions.[2]

Digesters manage manure in a way that enhances CH_4 production. Digester installation at existing agricultural operations where manure management produces little or no CH_4 (e.g., in a cold climate tank or pit storage where anaerobic conditions are limited by low temperatures and short retention times for manure) can actually increase the amount of CH_4 emitted. Even in some management systems that are primarily anaerobic, digesters can produce more CH_4 than the original management system emitted. A digester project can only claim reductions of those greenhouse gas emissions that occurred prior to the project. For this reason, greenhouse gas offset projects utilizing biogas recovery systems, and associated GHG emissions, must be carefully evaluated to determine and quantify actual emissions reductions resulting from the offset project.

This section provides information on the general parameters that the proposed manure methane collection and combustion project must match to use this performance standard.

Technology/Practice Introduced. This guidance document addresses the installation of an anaerobic digester to collect and convey CH_4 to a flare or gas utilization project. At some digesters, a flare will be the only combustion source where manure CH_4 is destroyed. At digesters that install energy or process heat technologies that combust manure gas, including reciprocating engines, boilers, furnaces or space heaters, these devices will be the main sites where manure gas is combusted. For safety purposes, most projects that produce energy or process heat include a flare in their design to combust the collected gas during periods when the digester is down for repair or maintenance.

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[2] EPA (2008) Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006. U.S. Environmental Protection Agency, Office of Atmospheric Programs, Washington, DC. USEPA #430-R-08-002

Project Size/Output. This accounting methodology applies to dairy and swine waste management systems that promote anaerobic environments regardless of size or production output.

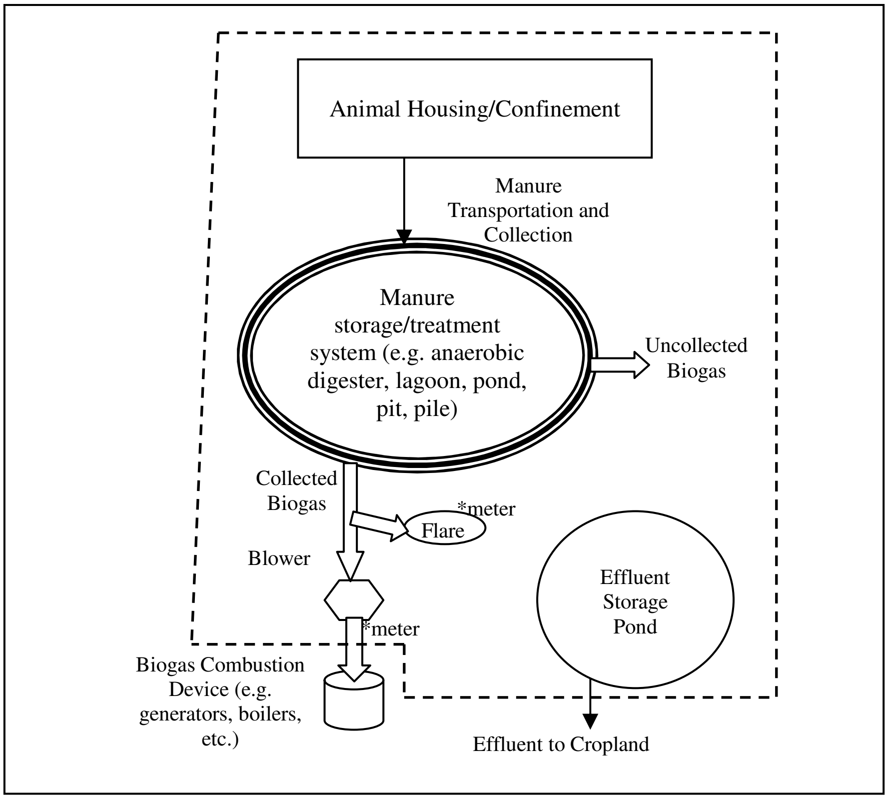
Project Boundary. This section provides guidance on which physical components, and associated greenhouse gases, must be included in the project boundary for a manure CH_4 collection and combustion project. This methodology relies on the assumption that all CH_4 that is collected enters the combustion device.

Physical Boundary. The physical boundary includes the following components of the animal production operation including project-related construction activities (see Figure 1):

- animal confinement areas, including barns or houses, open lots, and milking centers;
- manure collection systems, including flush or scrape systems, piping, ditches, and pits;
- manure storage and treatment areas, including tanks, pits, ponds, lagoons, digesters, stockpiles, compost piles;
- manure transportation, if manure is transported to a centralized treatment or storage facility; and
- piping, gas pumps or blowers, pressure regulators, condensate drains, and flares.

For projects that have an energy recovery component, the equipment used in the energy technology falls outside of the project boundary. Although equipment used for land application may result in project-related emissions it is not included in the physical boundary for this performance standard.

Figure 1. Physical Boundary for Manure Methane Collection and Combustion Projects



GHG Accounting Boundary. The GHG accounting boundary for the collection and combustion of manure biogas includes direct emissions of CH_4 and N_2O emissions from the manure and associated management processes, and emissions of CO_2, CH_4, and N_2O that result from electricity used for the blower or heater, any fuel combusted during the construction of the gas collection system, and from the transportation of manure specifically related to the project. Any GHG emissions from fuel used to assist and maintain flare operation are to be included as well. Emissions of CO_2 from the manure are not included because the CO_2 emitted from manure is from biogenic sources (sequestered in crops as livestock feedstuffs) and, therefore, these emissions do not increase concentrations of CO_2 in the atmosphere.

Methane emissions that escape from the digester cover, or from leaking valves or seals associated with the digester, are included in the GHG accounting boundary because these CH_4 emissions would not have occurred absent the project.

Temporal Boundary. Given the seasonal fluctuations in emissions from manure management systems, emission reductions should be estimated annually, using an average annual animal population that accounts for varying age and weight classes of animals on the farm. This approach also reflects variation in emissions from fluctuations in animal populations or production cycles. The temporal boundary also should include the emissions associated with construction and operation of the gas collection system.

Leakage. Leakage is an increase in greenhouse gas emissions or decrease in sequestration caused by the project but not accounted for within the project boundary. The underlying concept is that a particular project can produce offsetting effects outside of the physical boundary that fully or partially negate the benefits of the project. Although there are other forms of leakage, for this performance standard, leakage is limited to activity shifting – the displacement of activities and their associated GHG emissions outside of the project boundary.

Biogas recovery system projects are not expected to result in leakage of greenhouse gases outside the project boundary. If it is determined, however, that significant emissions that are reasonably attributable to the project occur outside the project boundary, these emissions must be quantified and included in the calculation of reductions, however, no specific quantification methodology is required. All associated activities determined to contribute to leakage should be monitored.

Regulatory Eligibility

The performance standard subjects greenhouse gas offset projects to a regulatory "screen" to ensure that the emission reductions achieved would not have occurred in the absence of the project due to federal, state or local regulations. In order to be eligible as a GHG offset project, GHG emissions must be reduced below the level effectively required by any existing federal, state, or local policies, guidance, or regulations. This may also apply to consent decrees, other legal agreements, or federal and state programs that compensate voluntary action.

Federal Regulations. There are currently no federal regulations or guidelines that have a bearing on the eligibility of manure management collection and combustion projects.[3]

State and Local Regulations. Most states have some form of odor or nuisance complaint process covering manure management operations. Most state regulations and guidelines are not expected to have a bearing on the eligibility of manure management collection and combustion projects. A few states have instituted stringent odor and other pollutant control requirements that could affect CH_4

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[3] EPA recently published national regulations for the Effluent Limitations Guidelines and the National Pollutant Discharge Elimination System Permit Regulations for Concentrated Animal Feeding Operations (CAFOs). Under this rule, large animal feeding facilities must provide storage that will contain manure and process wastewater plus the production area runoff from a major storm. Although facilities may elect to use innovative technologies, such as digesters, there is nothing in this regulation that requires the use of technologies and practices that would result in a reduction in greenhouse gas emissions.

emissions.[4] Manure management collection and combustion projects in those states which have regulations that require control of manure gases may not be eligible as greenhouse gas offset projects.

Local regulations for manure management are primarily for nuisance complaints. In most cases, there are no general requirements that would require control of manure gases and, therefore, impact GHG emissions.

Determining Additionality - Applying the Performance Threshold

This section describes the performance threshold (additionality determination) that a manure management collection and combustion project must meet or exceed in order to be eligible as a GHG offset project.

Additionality Determination. The additionality determination represents a level of performance that, with respect to emissions reductions or removals, or technologies or practices, is significantly better than average, compared with recently undertaken practices or activities in a relevant geographic area. Any project that meets or exceeds the performance threshold is considered "additional" or beyond that which would be expected under a "business-as-usual" scenario.

The type of performance threshold used for manure methane collection and combustion projects is practice-based. The threshold represents a level of performance (practice) that is beyond that expected of a typical manure management system, and is based on the suite of current technologies and common practices taking into account state minimum requirements for waste systems for each animal type.[5]

The majority of existing manure management systems does not include methane collection and combustion. The suite of current technologies and common practices includes very few digesters, and therefore, digester projects can typically be considered "beyond business as usual."

The determinant of additionality is whether there is already collection and combustion of manure gas at the proposed project site. There are two possible scenarios:

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[4] For example, Colorado has stringent regulations addressing odor concerns from commercial swine feeding operations, some of which could directly impact methane emissions from manure management operations, particularly swine lagoons. Minnesota, North Dakota, Missouri, California, Nebraska, and Wyoming all have standards in place for hydrogen sulfide emissions that affect agricultural operations. These generally stipulate that a permit be required for emissions or that steps are taken to reduce emissions at the monitoring point below the standard. California recently enacted legislation covering agricultural operations. Implementation of the bill could lead to the requirement for certain confined animal feeding operations to install air emissions control technologies that may affect methane emissions from manure management facilities.

[5] The dataset used in the development of the performance threshold is included in Appendix I.

1. If the dairy or swine operation is not currently collecting and combusting manure gas, the project is additional.

2. If the dairy or swine operation is currently collecting and combusting manure gas, the project is not additional.

Quantifying Emission Reductions

Quantifying emission reductions from manure management methane collection and combustion projects encompasses four steps: two are pre-project implementation (selecting the emissions baseline and estimating project emission reductions) and two are post-project implementation (monitoring and calculating actual project reductions).

Estimating Project Emission Reductions. The greenhouse gas emissions reductions from a manure methane collection and combustion project can be estimated using the procedures presented below and in the section on Calculating Actual Project Reductions.

Methane production from the digester project can also be calculated with AgSTAR FarmWare 3.0[6], a program developed by EPA to assist those considering installing an anaerobic digester. FarmWare can be used to calculate an emissions baseline for CH_4 from anaerobic lagoons with secondary storage and combined storage and treatment lagoons. The program should be used as directed with farm-specific information as inputs.

Selecting an Emission Baseline. The emission baseline for a manure management methane collection and combustion project is the manure management system in place prior to the project.

Listed below are typical manure management systems that could occur in the absence of the proposed project activity based on a review of current practices, designs, and technologies in the United States. All systems produce some greenhouse gases, however, the amount varies with type of operation and other factors, such as temperature and time. There are essentially five possible baseline manure management systems[7]:

1. **Conventional anaerobic lagoon**. An uncovered earthen structure designed and operated to combine waste stabilization and storage. Lagoon supernatant is typically used to flush manure from the associated confinement facilities to the lagoon. Anaerobic lagoons are designed for varying lengths of storage (up to a year or

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[6] FarmWare 3.0 can be downloaded from http://www.epa.gov/agstar/resources/handbook.html

[7] Manure management systems can consist of more than one of the five management systems listed. All practices/technologies that are within the project boundary must be included in emissions calculations. These five management systems are generally state minimum requirements for these animal types.

greater), depending on climate, manure loading rates, and other operational factors. The effluent from the lagoon typically is applied to adjacent cropland as fertilizer.

2. Slurry storage tanks and ponds. Manure is stored as excreted, or with some minimal addition of water to facilitate handling, in either tanks or earthen ponds, typically for periods ranging from six to twelve months. Slurry tank contents are typically pumped and applied to adjacent cropland as fertilizer.

3. **Deep pit storage.** Manure is collected and stored, usually with little or no added water, below a slatted floor in an enclosed animal confinement facility, usually for periods less than one year. Pit contents are typically removed and applied to fields as fertilizer.

4. **Solid storage.** Manure is stored in uncovered or covered piles or stacks, on a paved or unpaved surface, where accumulating manure may be removed periodically. Stacking of manure is possible due to the presence of a sufficient amount of bedding material or loss of moisture by evaporation. Periodically, stacked manure is disposed of by application to adjacent cropland as fertilizer.

5. Pasture and rangeland. The manure from grazing animals is allowed to lie as deposited, and is not collected.

Setting the Emissions Baseline. Baseline emissions are established using equations A, B and C below. Because of expected changes in the composition of the animal population during the life of a project, the emissions baseline must be re-established each year using the baseline manure management system selected above.

Farm-specific values, if available, should be input into the equations. Where they are not available, default values can be found in Appendix II, Tables II.a (VS, B_o, and N_{ex}), II.b (VS for cattle types), II.c (MCF for anaerobic lagoons, liquid/slurry systems, and digesters), and II.d (MCF for pasture, daily spread, solid storage, dry lot, and cattle deep litter), and II.e (EF).

Equation A. Input average annual population, weights ($W_{L,S}$) and VS rates for each livestock subgroup and manure management system into Equation A to determine CH_4 emissions in the baseline.

$$\textbf{Emissions}_{\textbf{baseline, CH4}} = \sum_{S} \textbf{MCF}_{\textbf{S}} \times \textbf{0.662} \times \textbf{21/1000} \times [\sum_{L} \textbf{W}_{\textbf{L, S}} \times \textbf{VS}_{\textbf{L, S}}\textbf{/1000kg} \times \textbf{365} \times \textbf{Pop}_{\textbf{L, S}} \times \textbf{B}_{\textbf{o, L}}]$$

Where:

Emissions $_{baseline,CH4}$ = CH_4 emissions for livestock managed in the baseline (TCO_2e)

L = Livestock subgroup

S = Manure management system

$W_{L,S}$ = Average live weight for livestock subgroup L, managed in system S (kg/head)

$VS_{L,S}$ = Volatile solids produced daily by livestock subgroup L, managed in system S in the baseline (kg VS/day/1000 kg animal mass)

$B_{o,L}$ = Maximum CH_4 producing capacity per kg of VS for livestock subgroup L (m^3 CH_4/kg VS)

$Pop_{L,S}$ = Population of livestock subgroup L managed in manure management system S

MCF_S = CH_4 conversion factor for manure management system S (See Appendix II, Tables II.c and II.d)

0.662 = kg CH_4 per m^3 CH_4

21 = Global warming potential of CH_4

1000 = kg per metric ton

Equation B. Next, input average annual population, weights ($W_{L,S}$) and N_{ex} rates for each livestock subgroup and manure management system into Equation B to determine N_2O emissions in the baseline.

$$Emissions_{baseline,\,N2O} = \sum_S EF_S \times 44/28 \times 310/1000 \times [\sum_L W_{L,S} \times Nex_{L,S} / 1000kg \times 365 \times Pop_{L,S}]$$

Where:

$Emissions_{baseline,\ N2O}$ = N_2O emissions livestock in the baseline (TCO_2e)

L = Livestock subgroup

S = Manure management system

$W_{L,S}$ = Average live weight for livestock subgroup L, managed in system S (kg/head)

$N_{exL,S}$ = Kjeldahl nitrogen excreted daily by livestock subgroup L managed in system S in the baseline (kg N/day/1000kg animal mass)

$Pop_{L,S}$ = Population of livestock subgroup L managed in manure management system S

EF_S = N_2O emission factor for manure management system S (kg N_2O -N/kg N excreted)

44/28 = Conversion factor, N_2O -N to N_2O

310 = Global warming potential of N_2O

1000 = kg per metric ton

Equation C. Calculate emissions from any energy use within the project boundary.

$$Emissions_{baseline,\ energy} = Fuel\ type * fuel\text{-}specific\ emission\ factor^{8}$$

Where:

Fuel Type = Quantity of each specific fuel used in existing manure management system (including transportation and electricity use)

Fuel-specific emission factor = CO_2, CH_4, and N_2O emitted from any fuel consumption or electricity-use (TCO_2e)

Equation D. Sum all CH_4, N_2O, and GHG emissions from energy to determine baseline emissions, using Equation D.

$$Emissions_{baseline} = Emissions_{baseline,\ CH4} + Emissions_{baseline,\ N2O} + Emissions_{baseline,\ energy}$$

Where:

$Emissions_{baseline}$ = Baseline GHG emissions for the accounting period (TCO_2e)

$Emissions_{baseline,\ CH4}$ = Output of Equation A (TCO_2e)

$Emissions_{baseline,\ N2O}$ = Output of Equation B (TCO_2e)

$Emissions_{baseline,energy}$ = Output of Equation C (TCO_2e)

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[8] If available, project-specific emissions factors should be used; if not then emission factors should be drawn from the most recent *Inventory of U.S. Greenhouse Gas Emissions and Sink*, available at http://www.epa.gov/climatechange/emissions/usinventoryreport.html, or Appendix II of this protocol.

Monitoring

Manure biogas collection and combustion projects can be monitored with direct measurements and by modeling. In that many digester projects are equipped with meters, direct measurement is the preferred method for determining CH_4 destruction. Nitrous oxide emissions are monitored by modeling.

All manure biogas collection and combustion greenhouse gas offset projects must also monitor any regulatory requirements (or changes in regulatory requirements) or substantive changes in the project that might affect the continued eligibility of the project as a greenhouse gas offset project.

Direct Measurement Methods for Determining Methane Emissions from Project. . Direct-measurement methods depend on two measurable parameters: 1) the rate of biogas flow to the combustion device; and 2) the CH_4 content in the biogas flow. These can be quantified by directly measuring the gas stream to the destruction device.

Continuous Metering. The instrumentation recommended for metering continuously measures both flow and gas concentration. Several direct measurement instruments also use a separate recorder to store and document the data.[9] Total gas combusted due to the digester can be determined through reading of the continuous meter and then used as input to the calculations of actual reductions. Internally, the instrumentation is performing its calculations using algorithms similar to Equation E used for monthly monitoring.

Monthly Sampling. The two primary instruments used in the monthly monitoring method are a gas flow meter and a gas composition meter. The gas flow meter must be installed as close to the gas combustion device as possible to measure the amount of gas reaching the device. Two procedures are used for data collection in the monthly monitoring method:

1. Calibrate monitoring instrument in accordance with the manufacturer's specifications.
2. Collect four sets of data: flow rate (scfm); CH_4 concentration (%); temperature (^{o}R); and pressure (atm) from the inlet biogas (before any treatment equipment using a monitoring meter specifically for CH_4 gas).

Equation E.

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[9] There are systems that integrate sampling and recording together using a gas chromatograph and a flow computer. Each integrated system is designed to be site-specific for the manure management system at which it will operate. The flow computer can be programmed with custom applications to allow it to calculate several parameters related to the properties of the gas collected, including directly relaying the methane content in metric tons.

$\text{Gas Combusted}_{project}$ = V x (C/100) x 0.0423 x (520/T) x (P/1) x (t) x 0.99 x (0.454/1000) x 21

Where:

$\text{Gas Combusted}_{project}$ = CH_4 combusted by the project (TCO_2e)
V = Volumetric flow (cfm)
C = CH_4 concentration in %
0.0423 = Density of CH_4 (lb/scf)
T = Temperature at which flow is measured (°R)[12]
P = Pressure at which flow is measured (atm)[12]
t = Time period since last monthly measurement (min)
0.99 = Destruction efficiency
0.454/1000 = Conversion factor (metric ton/lb)
21 = Global warming potential of CH_4

* The terms (520/T) x (P/1) are omitted if the instrument is internally corrected to standard temperature and pressure.

Modeling Method. The modeling method requires the same equations that are used to estimate baseline emissions. The equations are applied with actual data on animal populations for each animal type. At a minimum, the modeling method should be implemented annually. The equations, however, should also be recalculated whenever there is a change in the operation of the animal facility or the project that would affect any of the variables in these equations.

Modeling Method for Determining Nitrous Oxide Reduction from Project. The modeling method should be used by every project to estimate manure management system N_2O emissions. The modeling method uses Equation G, but with monitored values for population ($Pop_{L,S}$) and average live weight ($W_{L,S}$).

Calculating Actual Project Reductions. Quantifying project GHG emissions reductions occurs after the project has been implemented and monitored.

To ensure that reductions claimed from a manure management project are real and credible, only the reduction of those CH_4 emissions (and other associated greenhouse gases) that occurred under existing practices can be accounted for as offset reductions. Additionally, only the portion of the waste generated under existing practice that is collected and combusted in the digester can be accounted for as an emission reduction (i.e., if only 80 % of the existing waste is collected and combusted in the digester only this portion qualifies as an emissions reduction).

Baseline emissions must be calculated on what would have occurred in the baseline scenario, not on the amount of measured CH_4 destroyed by the installed digester project. Reductions estimates based on CH_4 collection and combustion resulting from a digester do not necessarily reflect real reductions resulting from the project.

The following GHGs must be quantified in order to estimate project emission reductions:

- CH_4 and N_2O generated by the baseline manure management system;
- CH_4 that is generated by the project but not combusted by the project;
- N_2O generated by the project manure management system; and,
- CO_2, CH_4, and N_2O emitted during any manure management system electricity generation and fuel combustion (including transportation in the baseline systems and the project).

To quantify project emission reductions, use the equations below with monitored values for livestock subgroups (Pop) and weights ($W_{L,S}$), and gas combusted by the project (Gas Combusted$_{,project}$). Population and weight numbers for both baseline and project calculations are those determined for the accounting period.

Project emissions can be quantified with equations F, G, and H below.

Equation F. First, run Equation F with actual monitored values for Gas Combusted$_{project}$ to determine CH_4 emissions from the project.

$$Emissions_{project,\,CH4} = \sum_{S} GasCombusted_{project,\,CH4}\,X[1 \div (CE \times 0.99) - 1]$$

Where:

Emissions$_{project,CH4}$ = Annual CH_4 emissions for livestock managed in digester (TCO_2e/yr)[10]

Gas Combusted $_{project}$ = Monitored gas combusted (TCO_{2e})

CE = Collection efficiency of the digester system (see Appendix II., II.f for guidance)

0.99 = Destruction efficiency

Equation G. Input average annual population, weights ($W_{L,S}$) and N_{ex} for each livestock subgroup into Equation G to determine N_2O emissions from the project.

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[10] Please note: If in the project some manure is not managed in the digester, CH4 emissions for the other manure management systems will need to be quantified (as in Equation A) and added to digester CH4 emissions to obtain total project CH4 emissions.

$$\textbf{Emissions}_{\textbf{project, N2O}} = \sum_{S} \textbf{EF}_{\textbf{S}} \times \textbf{44/28} \times \textbf{310/1000} \times [\sum_{L} \textbf{W}_{\textbf{L, S}} \times \textbf{Nex}_{\textbf{L, S}} \textbf{/1000kg} \times \textbf{365} \times \textbf{Pop}_{\textbf{L, S}}]$$

Where:

$\text{Emissions}_{\text{project, N2O}}$ = Annual N_2O emissions for livestock managed in project (TCO_2e)

L = Livestock subgroup

S = Manure management system

$W_{L,S}$ = Average live weight for livestock subgroup L, managed in system S (kg/head)

$N_{exL,S}$ = Kjeldahl nitrogen excreted daily by livestock subgroup L managed in system S in the baseline (kg N/day/1000kg animal mass)

$Pop_{L,S}$ = Population of livestock subgroup L managed in manure management system S

EF_S = N_2O emission factor for manure management system S (kg N_2O -N/kg N excreted)

44/28 = Conversion factor, N_2O -N to N_2O

310 = Global warming potential of N_2O

Equation H. Quantify project-related energy emissions.

Emissions $_{\textbf{project, energy}}$ **= Fuel type * fuel-specific emission factor**[11]

Where:

Fuel Type	= Quantify of each specific fuel used in project (including transportation and electricity use)
Fuel-specific emission factor	= CO_2, CH_4, and N_2O emitted from any fuel consumption or electricity-use

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[11] If available, project-specific emissions factors should be used; if not then emission factors should be drawn from the most recent *Inventory of U.S. Greenhouse Gas Emissions and Sinks,* available at http://www.epa.gov/climatechange/emissions/usinventoryreport.html, or Appendix III of this protocol.

Equation I. Quantify emissions from leakage associated with the project.

Emissions from Leakage = Fuel type * fuel specific emissions factor

Where:

Fuel Type = Quantity of each specific fuel used for activities outside of the project boundary

Fuel-specific emission factor = CO_2, CH_4, and N_2O emitted from any fuel consumption or electricity-use (TCO_2e)

Equation J. Finally, calculate the total project emissions for the accounting period, including emissions from energy associated with the project:

$$\mathbf{Emissions_{project} = Emissions_{project,\ CH4} + Emissions_{project,\ N2O} + Emissions_{project,\ energy}}$$

Where:

$\text{Emissions}_{\text{project}}$ = GHG emitted from the offset project (TCO_2e)

$\text{Emissions}_{\text{project, CH4}}$ = Output of Equation F

$\text{Emissions}_{\text{project, N2O}}$ = Output of Equation G

$\text{Emissions}_{\text{project, energy}}$ = Output of Equation H

Equation K. Project Reductions are simply calculated as the difference between the baseline and the project emissions adjusted for leakage.

$$\mathbf{Total\ Project\ Emission\ Reductions = (Emissions_{Baseline} - Emissions_{Project}) - Leakage}$$

Appendix I. Development of the Performance Threshold - Dataset

The primary data source for the performance threshold is the farm distribution and manure management system usage data compiled for the Manure Management portion of the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2004*. Additionally, data were collected on the number of farms by farm size and geographic location from the 2002 Census of Agriculture, and the implementation of anaerobic digesters at animal operations from the Interim Draft Winter 2006 AgSTAR Digest.[12]

Information compiled for the EPA's U.S. GHG inventory provides a breakdown of manure management system usage for dairy and swine operations. Table I.a below shows data compiled for systems in place in 2006. Of 91,988 dairy and 78,894 swine farm operations, there were 80 anaerobic digesters currently in operation: 62 (0.07%) for dairy manure and 18 (0.02%) for swine manure.[13] At more than 70 of the operational digester systems, the captured biogas is used to generate electricity and recover waste heat primarily for water heating. Four systems flare all of the captured gas for odor control, while the gas combustion method is unknown for six systems.

Table Ia. Dairy and Swine Operations in the U.S. by Manure Management System

	Number of Operations by Manure Management System						
Animal	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

Data were also disaggregated to determine whether digester installation was a common practice (and therefore not additional) in any animal production operation size range. As shown in Table Ib, 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.

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[12] Available at http://www.epa.gov/agstar/pdf/2005digest.pdf.

[13] There is one system in operation that digests both swine and dairy manure.

Table Ib. Distribution of Dairy and Swine Operations by Manure Management System and Farm Size

		Number of Operations by Farm Size						
Animal	**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 head	3,213	9	617	653	54	-	4,546
	1-199	68,954	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 head	-	3	3,990	5,219	832	8,869	18,913
	1-199 head	53,230	1	-	-	-	-	53,231

Spatial Area. The spatial area for this performance threshold includes all dairy and swine production operations in the United States. Table Ic shows the distribution of manure management practices by geographical region. There is no significant regional differentiation in manure management practices.

Table Ic. Distribution of Dairy and Swine Operations by Geographic Location

		Number of Operations by Geographic Location						
Animal	**U.S. Region**	**P/R/P**	**Anaerobic Digester**	**Lagoon**	**Liquid/ Slurry**	**Solid Storage**	**Deep Pit**	**Total**
Dairy	West	1,460	21	1,639	916	936	221	5,192
	Central	3,244	2	1,634	1,061	1,514	399	7,854
	Midwest	45,748	24	238	202	36	0	46,248
	South	2,890	1	300	205	430	22	3,848
	Mid-Atlantic	19,146	14	643	1,962	6,578	505	28,847
Swine	West	3,891	1	29	33	5	58	4,017
	Central	10,255	8	143	133	24	248	10,812
	Midwest	21,811	5	5,112	5,542	959	9,989	43,418
	South	5,732	0	190	122	24	245	6,313
	Mid-Atlantic	11,541	4	1,097	473	116	1,104	14,334

West = AK, CA, HI, OR, WA
Central = AZ, CO, ID, MT, NV, NM, OK, TX, UT, WY
Midwest = IL, IN, IA, KS, MI, MN, MO, NE, ND, OH, SD, WI
South = AL, AR, FL, GA, LA, MS, SC
Mid-Atlantic = CT, DE, KY, ME, MD, MA, NH, NJ, NY, NC, PA, RI, TN, VT, VA, WV

Temporal Range. The basic design and operation of most manure management systems on commercial livestock operations has not changed during the last 25 years. Modifications to the basic designs (such as solids separation) have been made, but these are exceptions to the basic design and operation. Therefore, the temporal range includes those management systems currently in place, as determined in 2006.[14]

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[14] ERG (2006) Performance Threshold Analysis and Summary. Memorandum to EPA from ERG. May 22, 2006.

Appendix II. Tables for estimating and calculating emissions

Table IIa. Animal Waste Characteristics (VS, B_o, and N_{ex} rates)

Animal Group	Average TAM (kg)	Source for TAM*	Maximum Methane Generation Potential, B_o (m^3 CH_4/kg VS added)	Source for B_o	Volatile Solids, VS (kg/day per 1,000 kg mass)	Source for VS rate	Nitrogen Excreted, N_{ex} (kg/day per 1,000 kg mass)
Dairy Cows	604	Safley 2000	0.24 (high roughage diet) 0.35 (low roughage diet) 0.36 (high/low roughage diet with solids separation)	Morris, 1976 Martin, 2005 Safley et al., 1990	See Table II.b		0.44
Dairy Heifers	476	Safley, 2000	0.17	Bryant et al., 1976	See Table II.b		0.31
Feedlot Heifers	420	USDA, 1996	0.33	Hashimoto, 1981	See Table II.b		0.30
NOF+ Bulls	750	Safley, 2000	0.17	Hashimoto, 1981	6.04	USDA 1996a	0.31
NOF Calves	118	ERG, 2003	0.17	Hashimoto, 1981	6.41	USDA 1996a	0.30
NOF Heifers	420	USDA, 1996	0.17	Hashimoto, 1981	See Table II.b		0.31
NOF Cows	533	NRC, 2000	0.17	Hashimoto, 1981	See Table II.b		0.33
Nursery Swine	13	ASAE, 2005	0.48	Hashimoto, 1984	8.89	ASAE, 2005	0.42
Grow/Finish Swine	70	ASAE, 2005	0.48	Hashimoto, 1984	5.36	ASAE, 2005	0.42
Breeding Swine	198	Safley, 2000	0.48	Hashimoto, 1984	2.60	USDA 1996a	0.24

* TAM = Typical animal mass. Where actual animal weights are available, they are preferred to defaults for estimating VS and N_{ex}.

+ NOF = Not on feed.

Table IIb. Volatile Solids (VS) Production for Cattle Subcategories by State (2006)

State	Dairy Cow kg/day/1000 kg	Dairy Heifer kg/day/1000 kg	NOF Cows kg/day/1000 kg	NOF Heifers kg/day/1000 kg	Feedlot Heifers kg/day/1000 kg
Alabama	8.28	6.64	6.74	7.55	3.45
Alaska	7.87	7.09	8.71	9.96	3.57
Arizona	11.41	7.09	8.71	9.99	3.59
Arkansas	7.55	6.48	6.72	7.53	4.15
California	9.59	6.13	6.57	7.37	3.58
Colorado	9.98	6.10	6.19	6.93	3.58
Connecticut	8.87	6.10	6.62	7.42	3.73
Delaware	8.33	6.10	6.62	7.43	3.60
Florida	8.88	6.64	6.74	7.55	3.53
Georgia	9.45	6.64	6.74	7.56	3.62
Hawaii	8.20	7.09	8.71	9.97	3.53
Idaho	11.23	7.09	8.71	10.02	3.63
Illinois	8.84	6.10	6.63	7.45	3.61
Indiana	9.07	6.10	6.63	7.44	3.64

Iowa	9.11	6.10	6.63	7.46	3.59
Kansas	9.34	6.10	6.19	6.93	3.57
Kentucky	7.89	6.64	6.74	7.56	3.41
Louisiana	7.28	6.48	6.72	7.52	3.56
Maine	8.47	6.10	6.62	7.42	3.45
Maryland	8.23	6.10	6.62	7.43	3.59
Massachusetts	8.31	6.10	6.62	7.41	3.53
Michigan	9.70	6.10	6.63	7.44	3.59
Minnesota	8.66	6.10	6.63	7.45	3.59
Mississippi	8.38	6.64	6.74	7.55	3.65
Missouri	7.91	6.10	6.63	7.43	3.59
Montana	8.67	6.10	6.19	6.90	3.64
Nebraska	8.59	6.10	6.19	6.93	3.57
Nevada	10.68	7.09	8.71	9.99	3.73
New Hampshire	8.94	6.10	6.62	7.42	3.53
New Jersey	7.97	6.10	6.62	7.43	3.53
New Mexico	10.96	7.09	8.71	10.00	3.53
New York	8.75	6.10	6.62	7.44	3.75
North Carolina	9.53	6.64	6.74	7.56	3.59
North Dakota	7.53	6.10	6.19	6.91	3.59
Ohio	8.42	6.10	6.63	7.44	3.66
Oklahoma	8.58	6.48	6.72	7.55	3.56
Oregon	10.12	7.09	8.71	9.99	3.72
Pennsylvania	8.89	6.10	6.62	7.44	3.59
Rhode Island	8.28	6.10	6.62	7.42	3.62
South Carolina	8.86	6.64	6.74	7.55	3.73
South Dakota	8.66	6.10	6.19	6.92	3.59
Tennessee	8.64	6.64	6.74	7.56	3.39
Texas	10.02	6.48	6.72	7.56	3.55
Utah	10.55	7.09	8.71	10.00	3.69
Vermont	8.60	6.10	6.62	7.43	3.47
Virginia	9.17	6.64	6.74	7.56	3.63
Washington	11.47	7.09	8.71	10.01	3.74
West Virginia	7.73	6.10	6.62	7.43	3.47
Wisconsin	8.73	6.10	6.63	7.44	3.58
Wyoming	8.38	6.10	6.19	6.91	3.59

Source: Lieberman and Pape, 2005. based on output from the cattle enteric fermentation model used in the U.S. GHG Inventory. Note: Enteric fermentation model uses estimation of gross energy (GE) intake, and its fractional digestibility (DE) to estimate VS production per animal unit: VS production (kg) = [GE - DE + (0.02 * GE)] / 20.1 (MJ/kg)

Table IIc. Methane Conversion Factors (MCF) for Anaerobic Lagoons, Liquid/Slurry Systems, and Digesters by Annual Average Temperature

Annual Average Temperature (° C)	Anaerobic Lagoons	Liquid/Slurry Systems	Digesters
≤10	66	17	90
11	68	19	90
12	70	20	90
13	71	22	90
14	73	25	90

15	74	27	90
16	75	29	90
17	76	32	90
18	77	35	90
19	77	39	90
20	78	42	90
21	78	46	90
22	78	50	90
23	79	55	90
24	79	60	90
25	79	65	90
26	79	71	90
27	80	78	90
≥28	80	84	90

Source: Anaerobic lagoon MCF based on Mangino, J., D. Bartram, and A. Brazy (2001) 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, 2002. Liquid/Slurry systems MCF from IPCC (2000) *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*, Intergovernmental Panel on Climate Change, National Greenhouse Gas Inventories Programme, Montreal, IPCC-XVI/Doc. 10 (1.IV.2000). May. Digester MCF is based on expert judgment.

Table IId. MCFs for Other Waste Management Systems

	Cool Climate	**Temperate Climate**	**Warm Climate**
Pasture	0.01	0.015	0.02
Daily Spread	0.001	0.005	0.01
Solid Storage	0.02	0.04	0.05
Dry Lot	0.01	0.015	0.05
Cattle Deep Litter (<1 month)	0.03	0.03	0.3
Cattle Deep Litter (>1 month)	0.21	0.44	0.76

Source: EPA (2008) Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006. U.S. Environmental Protection Agency, Office of Atmospheric Programs, Washington, DC. USEPA #430-R-08-002

Table IIe. N_2O Emission Factors (US GHG Inventory)

	Pasture	Daily Spread	Solid Storage	Dry Lot	Cattle Deep Bed (active mix)	Cattle Deep Bed (no mix)	Anaerobic Lagoons and Digesters	Liquid/ Slurry
N2O Emission Factor (EF)	0	0	0.005	0.02	0.07	0.01	0	0.005

Source: EPA (2008) Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006. U.S. Environmental Protection Agency, Office of Atmospheric Programs, Washington, DC. USEPA #430-R-08-002

Table IIf. Digester Collection Efficiencies

System Type	Cover Type	Percent of National Population	Methane Collection Efficiency	Description
Covered anaerobic lagoon (biogas capture)	Bank to bank, impermeable	<1%	95 to 100%	Methane reductions from biogas capture and utilization/flaring. Discounted from 100% due to cover leaks.
	Modular, impermeable	<1%	50 to 90%	Methane reductions from biogas capture and utilization/flaring. Percent methane reduction based on % surface area covered.
Complete mix, fixed film, or plug-flow digester	Enclosed vessel	<1%	98 to 100% (reduction from 100% due to system leaks)	Methane reductions from vessel containment of biogas and post-digester biogas combustion.

Source: Derived from data on cover effects as presented in Sommer et al., 2000, Bicudo et al., 2004, Nicolai et al., 2004, and Emission Solutions et al., 2000.

Appendix III. Default Emission Factors for other Energy Use

Table IIIa. CO_2 Emission Factors for Various Fuels

Fuel Type	kg CO_2/MMBtu
Natural Gas	53.06
Distillate Fuel Oil	73.15
Residual Fuel Oil	78.80
Coal	93.98

Note: Industrial coal value based on Year 2006 "Industrial Other Coal" value.
Source: Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2006, April 2008. U.S. Environmental Protection Agency.

Table IIIb. Default CH_4 and N_2O Emission Factors for Natural Gas, and Fuel Oil, Coal

Fuel Type	Greenhouse Gas	Emissions per Unit of Fuel Input (kg CO_2e/MMBtu)
Natural Gas	CH_4	0.105
	N_2O	0.031
Petroleum (Commercial sector)	CH_4	0.231
	N_2O	0.186
Petroleum (Industrial sector)	CH_4	0.063
	N_2O	0.186
Coal	CH_4	0.231
	N_2O	0.496

Sources: Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2006. U.S. Environmental Protection Agency, April 2008.

Table IIIc. Default CH_4 and N_2O Emission Factors for Electricity

Fuel Type	Greenhouse Gas	Emissions per Unit of Fuel Input (kg CO_2e/MMbtu)
Natural Gas	CH_4	0.021
	N_2O	0.031
Petroleum	CH_4	0.063
	N_2O	0.031
Coal	CH_4	0.021
	N_2O	0.496

Note: Electricity emissions of CH_4 and N_2O relate to the fuel used to produce the electricity. Information on fuel type will be needed to estimate CH_4 and N_2O.
Sources: Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2006. U.S. Environmental Protection Agency, April 2008.

Table IIId. Emission Factors for Electricity Use by Project Equipment by eGRID Subregion (2004)

eGRID Subregion	States included in eGRID Subregion	NERC Region	Emission factor for electricity used by project equipment (kg CO2/kWh)
AKGD* (Alaska Grid)	AK	ASCC	0.604
AKMS (Alaska Miscellaneous)	AK	ASCC	0.630
AZNM (WECC- Southwest)	AZ, CA, NM, NV, TX	WECC	0.634
CAMX (WECC- California)	CA, NV, UT	WECC	0.572
ERCT (Texas)	TX	ERCOT	0.600
FRCC (Florida)	FL	FRCC	0.612
HIMS (Hawaii- Miscellaneous)	HI	HICC	0.738
HIOA* (Hawaii- Oahu)	HI	HICC	0.783
MORE (Midwest- East)	MI, WI	MRO	1.005
MROW (Midwest- West)	IA, IL, MI, MN, MT, ND, NE, SD, WI, WY	MRO	1.050
NEWE (New England)	CT, MA, ME, NH, NY, RI, VT	NPCC	0.641
NWPP (WECC- Northwest)	CA, CO, ID, MT, NV, OR, UT, WA, WY	WECC	0.770
NYCW (New York- NYC, Westchester)	NY	NPCC	0.788
NYLI (New York- Long Island)	NY	NPCC	0.686
NYUP (New York- Upstate)	NJ, NY, PA	NPCC	0.821
RFCE (RFC- East)	DC, DE, MD, NJ, PA, VA	RFC	0.800
RFCM (RFC- Michigan)	MI	RFC	0.880
RFCW (RFC- West)	IL, IN, KY, MD, MI, OH, PA, TN, VA, WI, WV	RFC	0.951
RMPA (WECC- Rocky Mountains)	AZ, CO, NE, NM, SD, UT, WY	WECC	0.778
SPNO (SPP- North)	KS, MO	SPP	1.007
SPSO (SPP- South)	AR, KS, LA, MO, NM, OK, TX	SPP	0.699
SRMV (SERC- Mississippi Valley)	AR, LA, MO, MS, TX	SERC	0.634
SRMW (SERC- Midwest)	IA, IL, MO, OK	SERC	0.979
SRSO (SERC- South)	AL, FL, GA, MS	SERC	0.847
SRTV (SERC- Tennessee Valley)	AL, GA, KY, MS, NC, TN	SERC	0.941
SRVC (SERC- Virginia/Carolina)	GA, NC, SC, VA, WV	SERC	0.890

Note: The emission factors in Table III.d reflect variations in electricity use by project equipment across regions and load type (i.e., base versus non-baseload). Coincident peak demand factors from a 2007 ACEEE study were combined with EPA's eGRID emission factors for baseload and non-baseload power to derive the emission factors presented in this table.[15,16]

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[15] York, D. Kushler, M. Witte, P. "Examining the Peak Demand Impacts of Energy Efficiency: A Review of Program Experience and Industry Practice." American Council for and Energy-Efficient Economy (ACEEE). February 2007. http://www.aceee.org/pubs/u071.htm.

[16] The Emissions & Generation Resource Integrated Database (eGRID) is a comprehensive inventory of environmental attributes of electric power systems, available at http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html.

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