CLIMATE
ACTION
RESERVE

Mexico Livestock Project Reporting Protocol

Capturing and destroying methane
from manure management systems

Version 1.0

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1 Introduction

The Climate Action Reserve (the Reserve) Livestock Project Reporting Protocol – for capturing and destroying 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 emissions.

The Reserve is a nonprofit private organization that 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 certify their GHG emissions according to the Reserve's protocols.

Project developers that install manure biogas capture and destruction technologies use this document to register GHG reductions with the Reserve. The protocol 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 Reserve-approved verifiers. Guidance for verifiers to verify reductions is provided in the corresponding Livestock 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]

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.

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

2 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 destroys methane gas created as a result of manure management.

2.1 Project definition

For the purpose of this protocol, the GHG reduction project is the installation of a biogas control system[2] that captures and destroys 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 destroyed 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 destruction. “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.

Consistent with CDM methodology ACM0010 (V2 p.2), project developers must demonstrate that the depth of their anaerobic ponds/lagoons pre-project were sufficient to prevent algal oxygen production and create an oxygen-free bottom layer; which usually means at least 1 meter depth. 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 and the Handbook for management and control of wastewater and swine manure in Mexico.[4]

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

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[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.

[4] 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. For swine operations, see also the “Handbook for management and control of wastewater and swine manure in Mexico” of the Mexican Swine Confederation at http://www.porcimex.org/apoyos/aguasresiduales.htm.

to the primary effect of the project (reducing methane emissions). Section IV, The GHG Assessment Boundary, delineates the scope of the accounting framework.

2.2 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.

2.3 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 destroy 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 oxide 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 is not included within this protocol's accounting framework.[5]

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 GHG assessment boundary and GHG reduction calculation approach are designed to support such amendments. And, more broadly, new protocols may also be developed in the future to facilitate reduction opportunities in the agriculture sector (as well as other sectors).

3 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	→	*Mexican farms*
Eligibility Rule III:	Project Start Date	→	*August 15, 2008*

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[5] The Reserve anticipates the development of a supplement for this protocol for the reductions estimation and registration of activities that produces renewable electricity from biogas and that displaces the fossil-based electricity.

3.1 Additionality

The Reserve strives to support only projects that yield surplus GHG reductions, which are additional to what might have otherwise 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 Mexico. 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 7, Reporting Parameters, the project-crediting period is ten years.

The Regulatory Test.

Environmental legislation associated with livestock operations is framed by the "General Law for Ecological Equilibrium and Environmental Protection" (LGEEPA by its Spanish acronym), enacted in 1988. This law establishes that wastewater discharges from the agriculture and livestock sector are subject to federal and local regulation (Article 120, paragraph III), and that wastewater discharges to sewage systems in populated areas, to water bodies, and those that are spilled in the soil or are infiltrated in the sub-soil should comply with the necessary conditions to prevent water and soil contamination. To that end, the National Water Commission (CONAGUA by its Spanish acronym), in coordination with state and municipal governments, are responsible for setting the conditions on wastewater discharges, for issuing permits and licenses for water use and discharge, and for drafting and enforcing the corresponding Mexican Official Standards. With regard to wastewater discharges applicable to livestock operations, SEMARNAT has published two environmental standards:

- "NOM- 001-ECOL-1996", which sets the maximum contamination limits for wastewater discharge in water sources and other national resources, and
- "NOM-002-ECOL-1996, which establishes the maximum contaminant limits for wastewater discharges into urban and municipal sewage systems.

NOM-001 regulates the receptor water body and not the activity that discharges the water, establishing the maximum contamination limits according to 2 elements: the receptor water body (rivers, natural or artificial reservoirs, coastal waters, soil and natural wetlands) and the subsequent use of the wastewater (agricultural irrigation or urban public supply). For this reason, the wastewater quality monitoring is conducted prior to the discharge to the water bodies. In addition, compliance with NOM-001 is graduated according to the contamination load measured on the basis of the bio-chemical oxygen demand (BOD) or of the total suspended solids (TSS). Large polluters (discharging more than 3 tonnes per day of BOD or TSS) had to comply by January 1, 2000; the medium-sized polluters (from 1.2 to 3 tonnes per day), by January 1, 2005 and the remaining should comply with this standard by January 1, 2010.

The “General Law for the Prevention and Integral Waste Management”, published in 2003, identifies the residues of cattle raising activity as special management waste (Article 19, paragraph III). However, the definition of the waste that is subject to waste management plans corresponds to state or municipal authorities (Article 20).

With regard to state level regulation, the environmental laws regulate mainly the wastewater discharges from agricultural and livestock uses, and in most cases the authorization of permits and the compliance enforcement is transferred to the municipal governments. It is important to mention that the Livestock Law of the state of Michoacán, published in 2007, establishes in their Article 106 that the Rural Development Office of the state, in coordination with local cattle raisers organizations, will establish mandatory programs of manure management in relevant locations according to their animal concentration and it will supervise their compliance.

As to the municipal level, several environmental rules require the treatment of cattle manure, and the treatment systems should be authorized by the municipal agencies. This is the case of the municipalities of Mexicali, Rosarito and Tecate in the State of Baja California; of Irapuato in the State of Guanajuato; of Acapulco in the State of Guerrero; and of Ahome, Angostura, Cozalá and Culiacán in the State of Sinaloa. In most cases, the installation of an anaerobic digester is one of the several options of the authorized systems for manure treatment. However, the high costs of capital seem to prohibit the use of digesters as a practical mechanism for complying with these regulations.

The Reserve’s analysis of manure management practices in Mexico identified no regulations that obligate livestock owners to invest in a manure biogas control system. Although the Reserve found no regulations driving livestock operators to install a biogas control system, project developers pass the Regulatory Test by demonstrating that there are no state or federal regulations or local agency ordinances/rulings requiring the installation of a biogas control system.

Project developers are required to submit a signed attestation of title document that includes an attestation that the project has not been required to be implemented by any law, statute, regulation, court order, environmental mitigation or other mandate. All projects that pass this test are eligible to register reductions with the Reserve for the lifetime of the project-crediting period (ten years). However, if a regulatory agency with authority over a livestock operation passes a rule obligating the installation of a biogas control system, emissions reductions can be registered in the Reserve in the period from the project start date until the entry into force of the new regulation.

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.

3.2 Location

All projects located at livestock operations in Mexico 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 Mexico. Therefore, the Reserve will treat GHG reductions from all Mexico-based projects that follow the guidance in this protocol equally.

3.3 Project start date

On August 15, 2008, the State of California and the Border States of Baja California, Sonora, Nuevo León, Tamaulipas, Chihuahua and Coahuila, working with Pacific Gas and Electric and the California Climate Action Registry signed a Memorandum of Understanding (MOU), agreeing to work cooperatively to develop quantification and certification protocols for greenhouse gas (GHG) emission reduction projects in Mexico. The establishment of this agreement to support GHG reduction activities is the basis for the project start date criterion.

The start date of eligible projects must be on or after August 15, 2008. The project start date is defined as the date in which the biogas control system that complies with the established requirements begins operating.

Projects that began operating before being listed with the Reserve, but after August 15, 2008, are considered pre-existing projects. Pre-existing projects will be eligible to become listed with the Reserve for a period of 12 months from the effective date of this protocol (Version 1.0). This is to ensure that the Reserve is providing “early actors” (those that implemented a GHG reduction project prior to a project protocol being available for their project activity) enough time to list their project.[6] After this 12 month grace period, pre-existing projects are required to submit for listing within 6 months of becoming operational. Those that fail to list within this 6 month period will be considered non-additional and excluded from eligibility. Projects that began operating before August 15, 2008, are not eligible to register reductions according to this protocol.

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 August 15, 2008. Projects that began operating before this date 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 destroying methane gas from the treatment and/or storage of the project developer’s livestock waste.

4 The GHG Assessment Boundary

The GHG assessment boundary delineates the GHG sources and gases assessed by project developers to determine the net change in emissions associated with installing a biogas control system. This protocol’s assessment 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.

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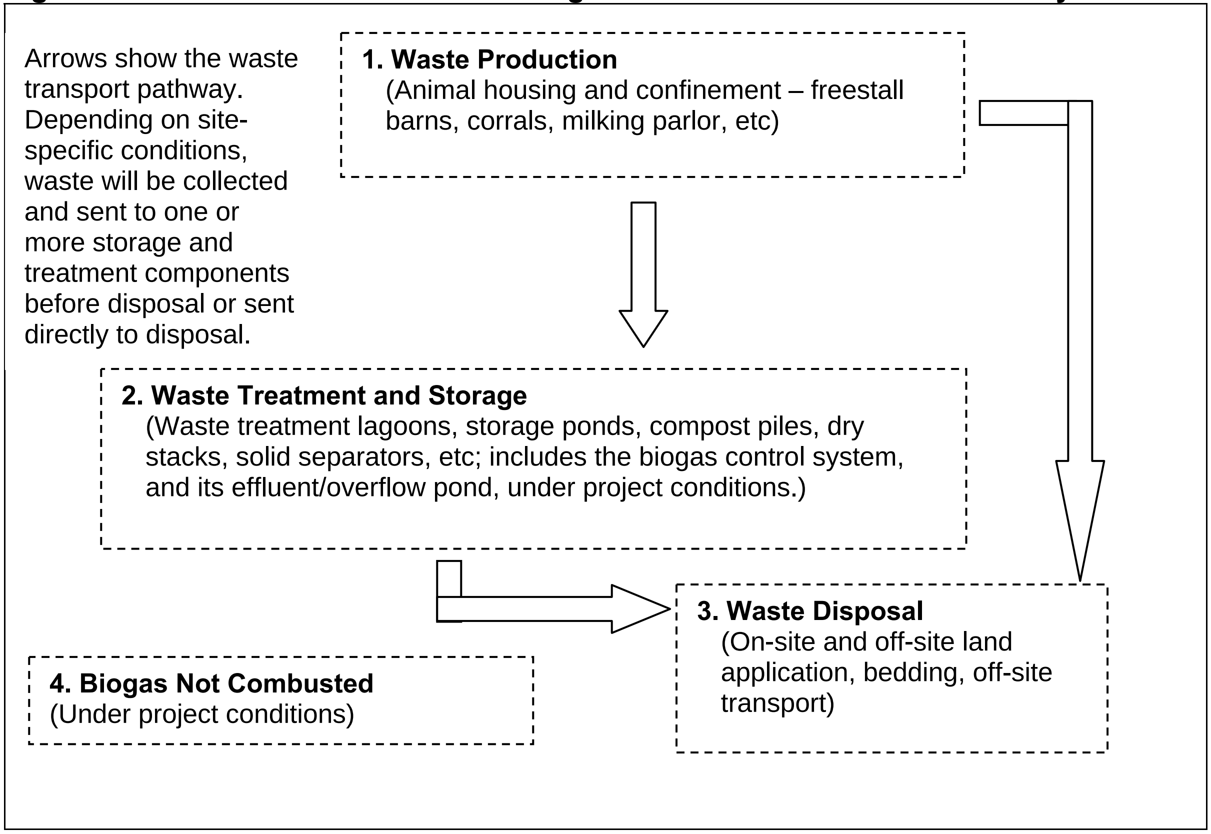
[6] A project is considered “listed” when the project developer has created an account with the Reserve, submitted the required Project Submission Form and related required documents, paid the project submission fee, and the Reserve has approved the project for listing.

4.1 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 gases. 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, and
- Waste disposal.

Figure 1: Schematic of the Manure Management GHG Assessment Boundary



Arrows show the waste transport pathway. Depending on site-specific conditions, waste will be collected and sent to one or more storage and treatment components before disposal or sent directly to disposal.

Figure 1 provides a general illustration of the assessment boundary; it encompasses the full manure management system (and includes GHG emissions from the biogas control system).

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.

4.2 Methane and carbon dioxide

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

- Methane
- Carbon dioxide

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.[7] 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 assessment boundary, which can either increase or decrease depending on project and farm specifics.[8] 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.[9]

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 to determine if carbon dioxide emissions are considered de minimis. Project developers are only required to calculate and document fuel use for annual carbon dioxide emissions if project carbon dioxide emissions show a variance greater than 5% of total baseline emissions. If project carbon dioxide emissions are found to be within 5% of total baseline emissions, then the project developer may use a best estimate technique to estimate carbon dioxide emissions. Whether the fuel records are documented or estimated, carbon dioxide emissions must be verified and reported to the Reserve annually.[10]

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

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[7] 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.

[8] Methane and nitrous oxide emissions from mobile and stationary combustion sources are not calculated.

[9] *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.

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

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

This protocol's GHG assessment 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.[11] The reason for the large uncertainty is the complex emissions pathway from organic nitrogen in livestock waste to nitrous oxide – the nitrification-denitrification cycle.[12]

As the state of science advances and methods to calculate nitrous oxide emissions at the farm-level improve, the Registry will incorporate them into this protocol. In fact, as the assessment boundary includes sources from waste production to disposal it is set-up to integrate nitrous oxide calculations. The Registry 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.

Table 1 relates GHG source categories to sources and gases, 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.

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

[12] Uncertainty also exists with estimations of baseline methane emission. The Reserve 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, Volatile Solids (VS) loading, and system VS retention time. Furthermore, all existing estimates of uncertainty (of which the Reserve is aware) involve the quantification of nitrous oxide at a national level, not a project-level. The Reserve 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: Manure management source categories, GHG sources, associated gases, and coverage in the manure management GHG assessment boundary

GHG Source Category	GHG Source	Associated GHGs*	Included in GHG assessment boundary
Waste Production (animal housing and confinement)	• Enteric fermentation	Methane	➢ *Not included* (no change due to project)[13]
	• 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*
Waste Disposal	• Land application	Nitrous oxide	➢ *Not Included*
	• Vehicle emissions (for land application and/or offsite transport)	Carbon dioxide	➢ *Included*
Biogas controls system	• Uncombusted or leaked gas	Methane	➢ *Included*
	• Biogas combustion	Carbon dioxide	➢ *Not Included*
	• Grid-electricity	Carbon dioxide	➢ *Not Included*

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

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[13] 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 Reserve will work with them to incorporate these emissions into the calculation procedure.

5 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).

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 Reserve has developed an Excel based calculation tool available at: http://www.climateactionreserve.org/how-it-works/protocols/adopted-protocols/livestock/current-livestock-project-protocol/.[14] The Reserve *recommends* the use of the Livestock Calculation Tool for all project calculations and emission reduction reports.[15]

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 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. As these new modeling methods become widely accepted and available, the Reserve will consider updating the protocol to incorporate these new approaches into the quantification methodologies.

The current methodology for quantifying the GHG impact associated with installing a biogas control system requires the use of both modeled reductions (following equations 2a - 2c and 3a - 3c) as well as the utilization of ex-post metered data from the biogas control system to be used as a check on the modeled reductions.

The Reserve recognizes that there can be material differences between modeled methane emission reductions and the actual metered quantity of methane that is captured and destroyed by the biogas control system due to digester start-up periods, venting events, and other biogas control system operational issues. These operational issues have the potential to result in substantially less methane destruction than is modeled, leading to an overestimation of GHG reductions in the modeled case.

To address this issue and maintain consistency with international best practice, the Reserve requires the modeled methane emission reduction results to be compared to the ex-post metered quantity of methane that is captured and destroyed by the biogas control system. The lesser of the two values will represent the total methane emission reductions for the reporting

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[14] The customized Livestock Calculation Tool for Mexico will be available in the forthcoming months.

[15] The software "PigMex" of the Mexican Swine Confederation is a useful support tool for swine operations. In its update, it will include biogas production estimations. However, actual GHG reductions must be calculated according to the guidance of this protocol.

period. Equation 1 below outlines the quantification approach for calculating the emission reductions from the installation of a biogas control system. [16]

Equation 1: GHG reductions from installing a biogas control system

$$\begin{aligned}\textit{Total GHG Reductions} &= (\textit{Modeled baseline emissions}_{CH4} - \textit{Project emissions}_{CH4}) \\ &\quad + (\textit{Baseline emissions}_{CO2} - \textit{Project emissions}_{CO2})\end{aligned}$$

The ($\textit{Modeled baseline emissions}_{CH4,}$ – $\textit{Project emissions}_{CH4}$) term shall be calculated according to equations 2a - 2c and equations 3a - 3c. The resulting aggregated quantity of methane reductions must then be compared to the ex-post quantity of methane that is metered and destroyed in the biogas collection system, as expressed in equation 4. In the case that the total ex-post quantity of metered and destroyed methane is less than the modeled methane reductions, the metered quantity of destroyed methane will replace the modeled methane reductions.

Therefore, the above equation then becomes:

$$\begin{aligned}\textit{Total GHG Reductions} &= (\textit{Total quantity of metered and destroyed methane}) \\ &\quad + (\textit{Baseline emissions}_{CO2} - \textit{Project emissions}_{CO2})\end{aligned}$$

5.1 Modeled Baseline Methane Emissions

Baseline emissions represent the GHG emissions within the GHG assessment boundary that would have occurred if not for the installation of the biogas control system.[17] 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.[18] 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 modeled baseline scenario using the prevailing system type in use for the geographic area, animal type, and farm size that corresponds to their operation.

Modeled baseline methane emissions. The procedure to determine the modeled 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.[19] 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

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[16] 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.

[17] The Reserve is working on developing guidance for the accounting of co-digestion activities. Co-digestion guidance should be published by early 2009.

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

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

for each livestock category, and account for the extent to which the waste management system handles each category's manure.

5.2 Modeled Baseline Methane Emissions Equations

Equation 2a: Modeled baseline methane emissions

$$BE_{CH4} = \left(\sum_{S,L} BE_{CH4,AS,L} + BE_{CH4,non-AS,L} \right)$$

Where,

BE_{CH4} = total annual baseline methane emissions, expressed in carbon dioxide equivalent (tCO_2e/yr)

$BE_{CH4,AS,L}$ = total annual baseline methane emissions from anaerobic storage/treatment systems by livestock category 'L', expressed in carbon dioxide equivalent (tCO_2e/yr)

$BE_{CH4,non-AS,L}$ = total annual baseline methane emissions from non-anaerobic storage/treatment systems, expressed in carbon dioxide equivalent (tCO_2e/yr)

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

$$BE_{CH4,AS} = \sum_{L,AS} VS_{\deg,AS,L} \times B_{0,L} \times 0.717 \times 0.001 \times 21$$

Where,

$BE_{CH4,AS}$ = total annual baseline methane emissions from anaerobic manure storage/treatment systems, expressed in carbon dioxide equivalent (tCO_2e/yr)

$VS_{deg,AS,L}$ = 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

0.717 = methane density conversion factor, m^3 to kg (at 0 °C and 1 atm pressure)[20]

0.001 = conversion factor from kg to metric tonnes

21 = Global Warming Potential factor of methane to carbon dioxide equivalent

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

Where,

$VS_{deg,AS,L}$ = 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 van't Hoff-Arrhenius factor = "the proportion of volatile solids that are biologically available for conversion to methane based on the monthly temperature of the system"[21]

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[20] These standard conditions refer to the International Union of Pure and Applied Technology (IUAPC). Methane density at the standard conditions of the National Institute of Standards and Technology (NIST), 20^oC and 1 atm is 0.668 kg CH_4/m^3.

[21] Mangino, et al.

Equation 2b continued

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

Where,

$VS_{avail,AS,L}$ = monthly volatile solids available for degradation in anaerobic storage/treatment system ‘AS’ by livestock category ‘L’(kg dry matter)

VS_L = volatile solids produced by livestock category ‘L’ on a dry matter basis (kg/animal/day) – *Important* - refer to Box 2 for guidance on using appropriate units for VS_L values from Appendix B.

P_L = annual average population of livestock category ‘L’ (based on monthly population data)

$MS_{AS,L}$ = percent of manure sent to (managed in) anaerobic manure storage/treatment system ‘AS’ from livestock category ‘L’ (%)[22]

dpm = days per month

0.8 = system calibration factor[23]

$VS_{avail-1,AS}$ = 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)[24]

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

Where,

f = the van’t Hoff-Arrhenius factor

E = activation energy constant (15,175 cal/mol)

T_1 = 303.16K

T_2 = monthly average ambient temperature (K = °C + 273). If $T_2 < 5$ °C then $f = 0.104$

R = ideal gas constant (1.987 cal/Kmol)

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[22] 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.

[23] 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.”

[24] 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).”

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

$$BE_{CH4,nAS} = \left(\sum_{L,S} P_L \times MS_{L,nAS} \times VS_L \times 365 \times MCF_{nAS} \times B_{0,L} \right) \times 0.717 \times 0.001 \times 21$$

Where,

$BE_{CH4,nAS}$ = total annual baseline methane emissions from non-anaerobic storage/treatment systems, expressed in carbon dioxide equivalent (tCO_2e/yr)
P_L = annual average population of livestock category ‘L’ (based on monthly population data
$MS_{L,nAS}$ = percent of manure from livestock category ‘L’ managed in non-anaerobic storage/treatment systems (%)
VS_L = volatile solids produced by livestock category ‘L’ on a dry matter basis (kg/animal/day) – *Important* - refer to Box 2 for guidance on using appropriate units for VS_L values from Appendix B.
365 = days in a year
$MCF_{,nAS}$ = methane conversion factor for non-anaerobic storage/treatment system ‘S’ (%) – See Appendix B, Table B.4
$B_{0,L}$ = maximum methane producing capacity for manure for livestock category ‘L’ (m^3 CH_4/kg of VS dry matter) – Appendix B, Table B.3
0.717 = methane density conversion factor, m^3 to kg (at 0°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

Box 2: Daily volatile solids for all livestock categories

VS_L values for all other livestock can be found in Appendix B, Table B.3.

Important - Units provided for all VS values in Appendix B are based on specific values for Mexico and default values from the IPCC guidelines. According to the CDM methodology ACM0010, it is recommended to adjust the VS values according to site specific animal mass data, using the following equation:

$$V_{SL} = VS_{table} \cdot \left(\frac{Mass_L}{MTP_L} \right)$$

Where,

VS_L = volatile solid excretion on a dry matter weight basis (kg/animal/day)
VS_{Table} = volatile solid excretion from lookup table (Tables B.3) (kg/animal/day)
$Mass_L$ = average animal mass for livestock category ‘L’ (kg), if site specific data is unavailable, use values from Appendix B, Table B.2
MTP_L = average animal mass (kg) from lookup table (Table B.2)

Modeled baseline methane calculation variables. The calculation procedure uses a combination of site-specific values and default factors.[25]

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_L. This value represents the daily 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).[26] This protocol requires that the VS value for all livestock categories be determined as outlined in Box 2.

$Mass_L$. This value is the annual average weight of the animals, per livestock category. Site specific livestock mass is preferred for all livestock categories. If site specific data is unavailable, Typical Average Mass (TAM) values can be used (Appendix B, Table B.2).

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. 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. As waste production is normalized for each livestock category, the percentage should be calculated as percent of population for each livestock category. For example, a dairy operation might send 85% of its milking cow's waste to an anaerobic lagoon and 15% could be deposited in a corral. In this situation an MS value of 85% would be assigned to equation 2b and 15% to equation 2c.

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 extent of anaerobic conditions present in the system, the temperature of the system, and the retention time of organic material in the system.[27]

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

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[25] The Reserve permits 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.
[26] IPCC 2006 Guidelines volume 4, chapter 10, p. 10.42.
[27] IPCC 2006 Guidelines volume 4, chapter 10, p. 10.43.

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.

The multiplication of "VS_{deg}" by "B_0" gives a site-specific quantification of the uncontrolled methane emissions that 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.[28]

Default MCF values for non-anaerobic manure storage/treatment are available in Appendix B, Table B.4, which are used for Equation 2c.

5.3 Project Methane Emissions

Project emissions are actual GHG emissions that occur within the GHG assessment 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. Methane emissions from manure storage and/or treatment systems other than the digester are modeled much the same as in the baseline scenario.

Project methane emissions. As shown in Equation 3, project methane emissions equal

- the amount of methane from waste treatment and storage not captured and destroyed 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. This includes all other manure treatment systems such as compost piles, solids storage, daily spread, etc.

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 3c will be the same as those in Equation 2a – 2c.

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[28] The method is derived from Mangino et al., "Development of a Methane Conversion Factor to Estimate Emissions from Animal Waste Lagoons"

5.4 Project Methane Emissions Equations

Equation 3: Project methane emissions

$$PE_{CH4} = [(PE_{CH4,\ BCS} + PE_{CH4,\ EP} + PE_{CH4,\ non\text{-}BCS}) \times 21]$$

Where,

PE_{CH4} = total annual project methane emissions, expressed in carbon dioxide equivalent (tCO_2e/yr)
$PE_{CH4,\ BCS}$ = annual methane emissions from the Biogas Control System (tCH_4/yr) – equation 3a
$PE_{CH4,\ EP}$ = annual methane emissions from the BCS Effluent Pond (tCH_4/yr) – equation 3b
$PE_{CH4,\ non\text{-}BCS}$ = annual methane emissions from sources in the waste treatment and storage category other than the Biogas Control System and associated Effluent Pond (tCH_4/yr) – equation 3c
21 = Global Warming Potential factor of methane to carbon dioxide equivalent

Equation 3a: Project methane emissions from the biogas control system

$$PE_{CH4,BCS} = \left(\mathrm{CH}_{4,\mathrm{meter}}\right)\left(\left(\frac{1}{BCE}\right) - BDE\right)$$

Where,

$PE_{CH4,\ BCS}$ = monthly methane emissions from the Biogas Control System (tCH_4/yr), to be aggregated annually
$CH_{4,meter}$ = the monthly quantity of methane collected and metered ($tCH_4/month$)
BCE = monthly methane collection efficiency of the Biogas Control System (% - as a decimal). The default value is 85% [29]
BDE = monthly methane destruction efficiency of the destruction device (% - as a decimal). In the event that there are is more than one destruction devices in operation in any given month, the weighted average destruction efficiency from all destruction devices is to be used (see BDE calculation below)

$$CH_{4,meter} = F \times (273.15/T)^{*} \times (P/1)^{*} \times CH_{4,conc} \times 0.717 \times 0.001$$

Where,

$CH_{4,meter}$ = the monthly quantity of methane collected and metered ($tCH_4/month$) [30]
F = measured volumetric flow of Biogas per month ($m^3/month$)
T = Temperature of the Biogas flow in K (Kelvin). ($K = {}^{o}C + 273.15$)
P = Pressure of the Biogas flow in atm
$CH_{4,conc}$ = measured methane concentration of Biogas from the most recent methane concentration measurement (% as a decimal)
0.717 = density of methane gas ($kgCH_4/m^3$) at STP (1atm, $0^{o}C$)
0.001 = conversion factor, kg to metric tons

** The terms (273.15/T) and (P/1) should be omitted if the continuous flow meter automatically corrects for temperature and pressure.*

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[29] Project developers have the option to justify a higher BCS collection efficiency based on verifiable documentation.

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

Equation 3a continued

$$BDE = \frac{\left(\begin{array}{l} (BDE_{of} \times F_{of}) + (BDE_{cf} \times F_{cf}) + (BDE_{lbic} \times F_{lbic}) + (BDE_{rbic} \times F_{rbic}) \\ + (BDE_{t} \times F_{t}) + (BDE_{b} \times F_{b}) + (BDE_{cng/\ln g} \times F_{cng/\ln g}) + (BDE_{ng} \times F_{ng}) \end{array} \right)}{F_{total}}$$

Where,

BDE_{of} = default methane destruction efficiency for open flare[31,32] = 0.96
F_{of} = total volume of gas fed to open flare (m^3)
BDE_{cf} = default methane destruction efficiency for enclosed flare[27,33] = 0.995
F_{cf} = total volume of gas fed to enclosed flare (m^3)
BDE_{lbic} = default methane destruction efficiency for lean-burn IC engine[27,29] = 0.936
F_{lbic} = total volume of gas fed to lean-burn IC engine (m^3)
BDE_{rbic} = default methane destruction efficiency for rich-burn IC engine[27,29] = 0.995
F_{rbic} = total volume of gas fed to rich-burn IC engine (m^3)
BDE_{t} = default methane destruction efficiency for microturbine or large gas turbine[27] = 0.995
F_{t} = total volume of gas fed to turbine (m^3)
BDE_{b} = default methane destruction efficiency for boilers[27] = 0.98
F_{b} = total volume of gas fed to boiler (m^3)
$BDE_{cng/lng}$ = default methane destruction efficiency for upgrade and use of gas as cng/lng vehicle fuel = 0.95
$F_{cng/lng}$ = total volume of gas upgraded for use as CNG/LNG fuel (m^3)
BDE_{ng} = default methane destruction efficiency for upgrade and injection into NG pipeline[34] = 0.98
F_{ng} = total volume of gas upgraded an injected into NG pipeline (m^3)
F_{total} = total volume of biogas captured and metered from biogas control system (m^3)

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[31] If available, the official source tested methane destruction efficiency shall be used in Equations 3a and Equation 4 in place of the default methane destruction efficiency. Otherwise, project developers have the option to use either the default methane destruction efficiencies provided, or the site specific methane destruction efficiencies as provided by a state or local agency accredited source test service provider, for each of the combustion devices used in the project case.

[32] Seebold, J.G., et. Al., Reaction Efficiency of Industrial Flares, 2003

[33] The default destruction efficiencies for this source are based on a preliminary set of actual source test data provided by the Bay Area Air Quality Management District. The default destruction efficiency values are the lesser of the twenty fifth percentile of the data provided or 0.995. These default destruction efficiencies may be updated as more source test data is made available to the Reserve.

[34] The Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories gives a standard value for the fraction of carbon oxidized for gas combustion of 99.5% (Reference Manual, Table 1.6, page 1.29). It also gives a value for emissions from processing, transmission and distribution of gas which would be a very conservative estimate for losses in the pipeline and for leakage at the end user (Reference Manual, Table 1.58, page 1.121). These emissions are given as 118,000kgCH4/PJ on the basis of gas consumption, which is 0.6%. Leakage in the residential and commercial sectors is stated to be 0 to 87,000kgCH4/PJ, which equates to 0.4%, and in industrial plants and power station the losses are 0 to 175,000kg/CH4/PJ, which is 0.8%. These leakage estimates are compounded and multiplied. The methane destruction efficiency for bio gas injected into the natural gas transmission and distribution system can now be calculated as the product of these three efficiency factors, giving a total efficiency of (99.5% * 99.4% * 99.6%) 98.5% for residential and commercial sector users, and (99.5% * 99.4% * 99.2%) 98.1% for industrial plants and power stations.

Equation 3b: Project methane emissions from the BCS effluent pond[35]

$$PE_{CH4,EP} = VS_{ep} \times B_{o,ep} \times 365 \times 0.717 \times MCF_{ep} \times 0.001$$

Where,

$PE_{CH4,\,EP}$ = methane emissions from the Effluent Pond (tCH_4/year)
VS_{ep} = volatile solid to effluent pond (kg/day) – 30% of the average daily VS entering the digester[36]
$B_{o,ep}$ = maximum methane producing capacity (m^3CH_4/kg of VS dry matter)[37]
365 = number of days in a year
0.717 = conversion factor for m^3 to kg
MCF_{ep} = methane conversion factor (%), Appendix B, Table B.4. Project developers should use the *liquid slurry* MCF value for effluent ponds
0.001 = conversion factor from kg to metric tones

$$VS_{ep} = \left(\sum_{L} (VS_L \times P_L \times MS_{L,BCS}) \right) \times 0.3$$

Where,

VS_L = volatile solids produced by livestock category 'L' on a dry matter basis (kg/animal/day) – *Important* - refer to Box 2 for guidance on using appropriate units for VS_L values from Appendix B
P_L = annual average population of livestock category 'L' (based on monthly population data
$MS_{L,BCS}$ = percent of manure from livestock category 'L' that is managed in the Biogas Control System
0.3 = default value representing the amount of Volatile Solids that exit the digester as a percentage of the Volatile Solids entering the digester

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[35] 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 using equation 3b.

[36] Per ACM0010 (V2 Annex I).

[37] 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. Supporting laboratory data and documentation need to be supplied to the verifier to justify the alternative value.

Equation 3c: Project methane emissions from *non*-biogas control system related sources[38]

$$PE_{CH4,nBCS} = \left(\sum_{L} (EF_{CH4,L}(nBCSs) \times P_L) \right) \times 0.001$$

Where,

$PE_{CH4,\,nBCS}$ = 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

$$EF_{CH4,L}(nBCSs) = (VS_L \times B_{o,L} \times 365 \times 0.717) \times \left(\sum_{S} (MCF_S \times MS_{L,S}) \right)$$

Where,

$EF_{CH4,L}$ *(nBCSs)* = methane emission factor for the livestock population ($kgCH_4$/head/year) from non-biogas control system related sources

VS_L = volatile solids produced by livestock category 'L' on a dry matter basis (kg/animal/day) – *important* - refer to Box 2 for guidance on using appropriate units for VS_L values from Appendix B.

$B_{o,L}$ = maximum methane producing capacity for manure for livestock category 'L' (m^3 CH_4/kg of VS dry matter), Appendix B, Table B.3

365 = number of days in a year

0.717 = conversion factor for m^3 to kg

MCF_S = methane conversion factor for system component 'S' (%), Appendix B, Table B.4

$MS_{L,S}$ = percent of manure from livestock category L that is managed in non-BCS system component 'S' (%)

5.5 Metered Methane Destruction Comparison

As described above, the Reserve requires all projects to compare the modeled methane emission reductions for the reporting period, as calculated in equations 2a - 2c and 3a - 3c above, with the actual metered amount of methane that is destroyed in the biogas control system over the same period. The lesser of the two values is to be used as the total methane emission reductions for the reporting period in question.

In order to calculate the metered methane reductions, the monthly quantity of biogas that is metered and destroyed by the biogas control system must be aggregated over the reporting period. In the event that a project developer is reporting reductions for a period of time that is

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[38] 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).

less than a full year, the total modeled methane emission reductions would be aggregated over this time period and compared with the metered methane that is destroyed in the biogas control system over the same period of time. For example, if a project is reporting and verifying only 6 months of data, July – December for instance, then the modeled emission reductions over this 6 month period would be compared to the total metered biogas destroyed over the same six month period, and the lesser of the two values would be used as the total methane emission reduction quantity for this 6 month period.

Equation 4 below details the metered methane destruction calculation.

Equation 4: Metered methane destruction

$$CH_{4,destroyed} = \sum_{months} (CH_{4,meter} \times BDE) \times 21$$

Where,

$CH_{4,destroyed}$	=	The aggregated quantity of methane collected and destroyed (tCO2e/yr) during the reporting period
$CH_{4,meter}$	=	the monthly quantity of methane collected and metered (tCH4/month). See equation 3a for calculation guidance
BDE	=	the monthly methane destruction efficiency of the combustion device (% as a decimal). In the event that there is more than one destruction device in operation in any given month, the weighted average destruction efficiency from all combustion devices is to be used. See equation 3a for calculation guidance
21	=	Global Warming Potential factor of methane to carbon dioxide equivalent

Determining the methane emission reductions

- If $CH_{4,destroyed}$ is less than ($BE_{CH4} – PE_{CH4}$) as calculated in equations 2a - 2c and 3a - 3c for the reporting period, then the methane emission reductions are equal to $CH_{4,destroyed.}$
- Otherwise, the methane emission reductions are equal to ($BE_{CH4} – PE_{CH4}$).

5.6 Carbon Dioxide Emissions

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 to determine if carbon dioxide emissions are considered de minimis. Project developers are only required to calculate and document fuel use for annual carbon dioxide emissions calculations if project carbon dioxide emissions show a variance greater than 5% of total baseline emissions. If project carbon dioxide emissions are found to be within 5% of total baseline emissions, then the project developer may use a best estimate technique to estimate these de minimis carbon dioxide emissions. All carbon dioxide must be reported within the GHG assessment boundary, including all estimated de minimis carbon dioxide emissions. [39]

For mobile and stationary combustion sources, project developers multiply the quantity of fuel consumed by a fuel-specific emission factor (see Equation 5 below). Examples of sources

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[39] This is consistent with guidance in the Reserve’s GRP and WRI’s GHG Project Protocol regarding the treatment of significant secondary effects.

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.

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

For additional information on calculating mobile and stationary combustion sources, project developers can refer to the guidance in the Reserve's General Reporting Protocol.

Equation 5 below calculates the net change in anthropogenic carbon dioxide emissions resulting from the project activity.

Equation 5: Carbon dioxide emission calculations

$$CO_{2,net} = (BE_{CO2MSC} - PE_{CO2MSC})$$

Where,

$CO_{2,net}$ = net change in anthropogenic carbon dioxide emissions from Mobile and Stationary Combustion sources resulting from project activity (tCO2/yr)
BE_{CO2MSC} = total annual baseline carbon dioxide emissions (tCO2/yr) from Mobile and Stationary Combustion sources (see equation below)
PE_{CO2MSC} = total annual project carbon dioxide emissions (tCO2/yr) from Mobile and Stationary Combustion sources (see equation below)

All stationary and mobile combustion are calculated using the equation:

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

Where,

$CO2_{MSC}$ = anthropogenic carbon dioxide emissions (tCO2) from Mobile and Stationary Combustion sources
$EF_{CO2,f}$ = fuel-specific emission factor f (kg CO_2/GJ), Appendix B, Table B.5
QF_c = quantity of fuel consumed for each mobile and stationary emission source 'c' (GJ/yr)[40]
0.001 = conversion factor from kg to metric tonnes

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[40] If the quantity of fuel consumed is given in mass (kg or tones) or volume (lt or m^3) units, convert it into energy units by multiplying the fuel quantity by its net calorific value. Use the calorific value provided by the fuel supplier or a laboratory analysis, if it is not available use the net calorific values provided in Appendix B, Table B.6.

6 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 for each component of the system. According to this protocol, methane emissions from the biogas control system are monitored with measurement equipment that directly meters:

- the total flow of biogas, measured and recorded continuously (i.e., every 15 minutes) or totalized and recorded at least daily, adjusted for temperature and pressure, prior to delivery to the destruction device(s);
- the methane concentration of the biogas to the destruction devices, measured with a continuous analyzer or, alternatively, with quarterly measurements using a calibrated portable gas analyzer; and
- the flow of biogas, measured and recorded continuously (i.e., every 15 minutes) or totalized and recorded at least daily, adjusted for temperature and pressure, that is delivered to each destruction device.

The hourly operational activity of the biogas collection system and the destruction devices shall be monitored and documented to ensure actual methane destruction. GHG reductions will not be accounted for during periods which the destruction device was not operational. This period is defined as the time between the flow reading preceding and following the outage.

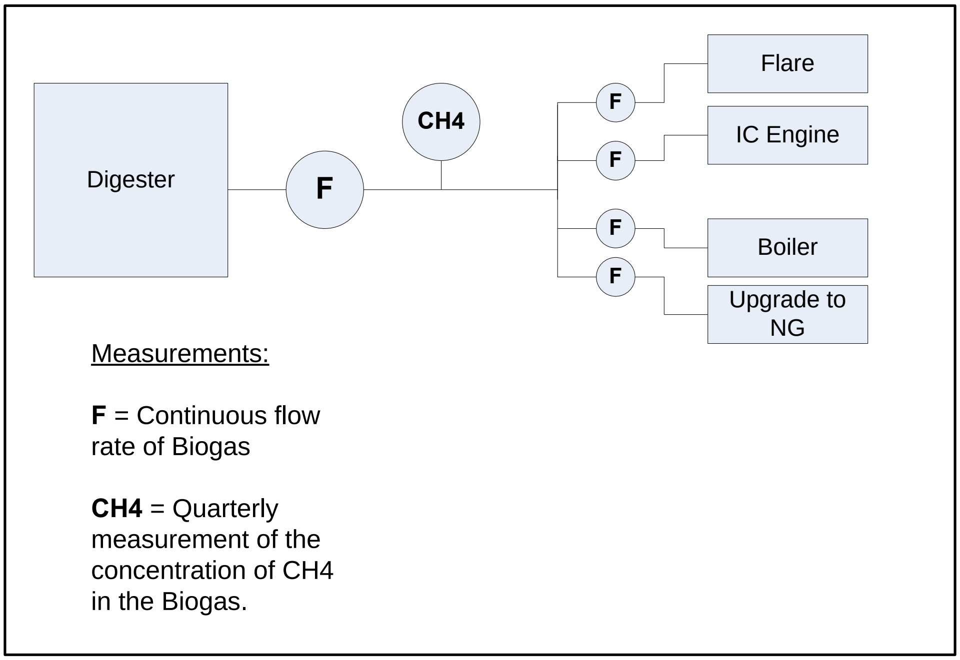
The measurement equipment is sensitive for gas quality (humidity, particulate, etc.), so a strong QA/QC procedure for the calibration of this equipment should be built in the monitoring plan. Monitoring instruments shall be inspected, cleaned and calibrated or field checked at least semi-annually, in accordance with manufacturer's specifications. All gas flow meters and continuous methane analyzers must be:

- Cleaned, inspected, and field checked on a semi-annual basis, using either a portable flow velocity instrument (such as a pitot tube) or manufacturer specified guidance, and
- Calibrated by the manufacturer or an approved calibration professional on an annual basis.

If portable calibration instrument are used, such as a pitot tube or a calibrated portable gas analyzer, the portable instruments shall be calibrated at least annually at an ISO 17025 accredited laboratory. Portable gas analyzers must be field calibrated prior to each use, and cleaned, inspected and professionally serviced according to manufacturer specifications.

Project developers shall create a written monitoring plan which describes the frequency of data acquisition, the record keeping plan (see section 7.2 for minimum record keeping requirements) and the frequency of instrument calibration activities. The monitoring plan shall also include QA/QC provisions to ensure that data acquisition and meter calibration are carried out consistently and with precision. Figure 2 represents the suggested arrangement of the biogas flow meters and methane concentration metering equipment.

Figure 2: Suggested arrangement of biogas metering equipment



Note: The number of flow meters must be sufficient to track the total flow as well as the flow to each combustion device. The above scenario includes one more flow meter than would be necessary to achieve this objective.

Flow meters should be installed along the header pipe at a section that provides a straight section of pipe sufficient to provide laminar gas flow, as turbulent flow resulting from bends or obstructions in the pipe can cause interference with flow measurements which rely on differential pressure.[41]

In situations where the flow rate or methane concentration monitoring equipment has failed a calibration test (tested to be outside of allowable 5% margin of error), or is missing data, the project developer should apply the data substitution methods provided in Appendix D.

In the event that the destruction device monitoring equipment is inoperable, then all metered biogas shall be assumed to be released to atmosphere during the period of inoperability by assuming a destruction efficiency of zero for the period of inoperability. In equation 3a the monthly destruction efficiency (BDE) value shall be adjusted accordingly. As an example, consider the primary destruction device to be an open flare with a BDE of 96% and it is found to be inoperable for a period of 5 days of a 30 day month. In this case the monthly BDE would be (0.96*25)/30 = 80%.

Provisions for monitoring other variables to calculate baseline and project emissions are provided in table 2. The parameters are organized by general project factors then by the calculation methods.

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[41] Solid Waste Association of North America, 1997. Landfill gas operation and maintenance, manual of practice.

Table 2: Project Monitoring Parameters

Parameter	Description	Data unit	calculated (c) measured (m) reference(r) operating records (o)	Measurement frequency	Comment
General Project Parameters					
Regulations	Project developer attestation to compliance with regulatory requirements relating to the manure digester project	Environmental regulations	n/a	Annual	Information used to: 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. *Verifier:* Determine regulatory agencies responsible for regulating livestock operation; Review regulations and site permits pertinent to livestock operation
L	Type of livestock categories on the farm	Livestock categories	o	Monthly	Select from list provided in Appendix B, Table B.2. *Verifier:* Review herd management software; Conduct site visit; Interview operator.
MS_L	Fraction of manure from each livestock category managed in the baseline waste handling system 'S'	Percent (%)	o	Annually	Reflects the percent of waste handled by the system components 'S' pre-project. 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. *Verifier:* Conduct site visit; Interview operator; Review baseline scenario documentation.

Parameter	Description	Data unit	calculated (c) measured (m) reference(r) operating records (o)	Measurement frequency	Comment
P_L	Average number of animals for each livestock category	Population (# head)	o	Monthly	*Verifier*: Review herd management software;[42] Review federal, state or local air and water quality agency reporting submissions, if available.
$Mass_L$	Average animal mass by livestock category	kg	o,r	Monthly	From operating records, or if onsite data is unavailable, from lookup table (Appendix B Table B.2). *Verifier*: Conduct site visit; Interview livestock operator; review average daily gain records, operating records.
T	Average monthly temperature at location of the operation	^oC	m/o	Monthly	Used for van't Hoff Calculation and for choosing appropriate MCF value. *Verifier*: Review temperature records obtained from weather service.
Baseline Methane Calculation Variables					
$B_{0,L}$	Maximum methane producing capacity for manure by livestock category	(m^3 CH_4/kgVS)	r	Annually	From Appendix B, Table B.3. *Verifier*: Verify correct value from table used.
MCF_S	Methane conversion factor for manure management system component 'S'	Percent (%)	r	Annually	From Appendix B, Table B.4 Differentiate by livestock category *Verifier*: Verify correct value from table used.
VS_L	Daily volatile solid production	(kg/animal/day)	r,c	Annually	Appendix B, Table B.3; see Box 2 for guidance on adjusting default values. *Verifier*: Ensure appropriate year's table is used; review data units.

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[42] For swine operations and in case that the farm operator does not have a herd management software, it is recommended to use the software "PigMex" as a supporting tool.

Parameter	Description	Data unit	calculated (c) measured (m) reference(r) operating records (o)	Measurement frequency	Comment
VS_{avail}	Monthly volatile solids available for degradation in each anaerobic storage system, for each livestock category	kg	c,o	Monthly	Calculated value from operating records. Recommend Reserve's Livestock Calculation Tool for all calculations. *Verifier*: Ensure proper use of Reserve's Livestock Calculation Tool, review operating records
VS_{deg}	Monthly volatile solids degraded in each anaerobic storage system, for each livestock category	kg	c,o	Monthly	Calculated value from operating records. Recommend Reserve's Livestock Calculation Tool for all calculations. *Verifier*: Ensure proper use of Reserve's Livestock Calculation Tool, review operating records
f	van't Hoff-Arrhenius factor	n/a	c	Monthly	The proportion of volatile solids that are biologically available for conversion to methane based on the monthly temperature of the system. Recommend Reserve's Livestock Calculation Tool for all calculations. *Verifier*: Ensure proper use of Reserve's Livestock Calculation Tool, review calculation; review temperature data
Project Methane Calculation Variables – BCS + Effluent Pond					
$CH_{4, destroyed}$	Aggregated amount of methane collected and destroyed in the biogas control system	Metric tonnes of CH4	c,m	Annually	Calculated as the collected methane times the destruction efficiency (see the '$CH_{4,meter}$' and 'BDE' parameters below) *Verifier:* Review meter reading data, confirm proper operation of the destruction device(s), ensure data is accurately aggregated over the correct amount of time.

Parameter	Description	Data unit	calculated (c) measured (m) reference(r) operating records (o)	Measurement frequency	Comment
$CH_{4,meter}$	Amount of methane collected and metered in biogas control system	Metric tonnes of CH4 (tCH4)	c,m	Monthly	Calculated from biogas flow and methane fraction meter readings (See 'F' and '$CH_{4,conc}$' parameters below). *Verifier*: Review meter reading data; confirm proper operation, in accordance with the manufacturer's specifications, confirm meter calibration data.
F	Monthly volume of biogas from digester to destruction devices	m^3/month	m	Continuously, aggregated monthly	Measured and recorded continuously from flow meter (every 15 minutes) or in an accumulated manner at least daily. Data to be aggregated monthly. *Verifier*: Review meter reading data; confirm proper aggregation of data; confirm proper operation in accordance with the manufacturer's specifications and confirm meter calibration data.
T	Temperature of the biogas	°C (Celsius)	m	Continuously, averaged Monthly	Measured to normalize volume flow of biogas to STP (0^oC, 1 atm). No separate monitoring of temperature is necessary when using flow meters that automatically measure temperature and pressure, expressing biogas volumes in normalized cubic meters.
P	Pressure of the biogas	atm	m	Continuously, averaged Monthly	Measured to normalize volume flow of biogas to STP (0^oC, 1 atm). No separate monitoring of pressure is necessary when using flow meters that automatically measure temperature and pressure, expressing biogas volumes in normalized cubic meters.

Parameter	Description	Data unit	calculated (c) measured (m) reference(r) operating records (o)	Measurement frequency	Comment
$CH_{4,conc}$	Methane concentration of biogas	Percent (%)	m	Quarterly	Use a direct sampling approach that yields a value with at least 95% confidence. Samples to be taken at least quarterly. Calibrate monitoring instrument in accordance with the manufacturer's specifications. *Verifier*: Review meter reading data; confirm proper operation, in accordance with the manufacturer's specifications.
BDE	Methane destruction efficiency of destruction device(s)	Percent (%)	r,c	Monthly	Reflects the actual efficiency of the system to destroy captured methane gas - accounts for different destruction devices. See guidance and default factors in equation 3a. *Verifier*: Confirm proper and continuous operation in accordance with the manufacturer's specifications.
BCE	Biogas capture efficiency of the anaerobic digester, accounts for gas leaks.	Percent (%)	r	Annually	Default value is 85%. Project developers may justify a higher BCE using verifiable evidence. *Verifier:* Review operation and maintenance records to ensure proper functionality of BCS. Assess claims that BCE is higher than default.
VS_{ep}	Average daily volatile solid of digester effluent to effluent pond	kg/day	c	Annually	If project uses effluent pond, equals 30% of the average daily VS entering the digester (From ACM0010 -V2 Annex I) *Verifier*: Review VS_{ep} calculations.

Parameter	Description	Data unit	calculated (c) measured (m) reference(r) operating records (o)	Measurement frequency	Comment
$MS_{L,BCS}$	Fraction of manure from each livestock category managed in the biogas control system	Percent (%)	o	Annually	Used to determine the total VS entering the digester. The percentage should be tracked in operational records. *Verifer*: Check operational records and conduct site visit.
Bo_{ep}	Maximum methane producing capacity for manure to effluent pond	(m^3 CH_4/kgVS)	c	Annually	An average of the Bo_{ep} value of the operation's livestock categories that contributes manure to the biogas control system. *Verifier:* Check calculation.
MCF_{ep}	Methane conversion factor for biogas control system effluent pond	Percent (%)	r	Annually	Appendix B, Table B.4, (From IPCC v.4, chapter 10, Table 10.17) Project developers should use the *liquid slurry* MCF value. *Verifier*: Verify value from table.
Project Methane Calculation Variables – Non-BCS Related Sources					
$MS_{L,S}$	Fraction of manure from each livestock category managed in non-anaerobic manure management system component 'S'	Percent (%)	o	Monthly	Based on configuration of manure management system, differentiated by livestock category. *Verifier*: Conduct site visit; interview operator.
$EF_{CH4,L}$ (nBCSs)	Methane emission factor for the livestock population from non-BCS-related sources	(kgCH_4/head/year)	c	Annually	Emission factor for all non-BCS storage systems, differentiated by livestock category. See equation 3c. *Verifiers*: review calculation, operations records.
Baseline and Project CO2 Calculation Variables					
$EF_{CO2,f}$	Fuel-specific emission factor for mobile and stationary combustion sources	kg CO_2/TJ	r	Annually	Refer to Appendix B, Table B.5 for emission factors. If biogas produced from digester is used as an energy source, the EF is zero. *Verifier*: review emission factors

Parameter	Description	Data unit	calculated (c) measured (m) reference(r) operating records (o)	Measurement frequency	Comment
QF_c	Quantity of fuel used for mobile/stationary combustion sources	TJ/year or lt/year or m^3/year	o,c	Annually	Fuel used by project for manure collection, transport, treatment/storage, and disposal, and stationary combustion sources including supplemental fossil fuels used in combustion device. *Verifer:* Review operating records and quantity calculation, review calorific values.

7 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. All direct methane and carbon dioxide must be reported within the GHG assessment boundary, including all estimated de minimis carbon dioxide emissions. Project developers must submit verified emission reduction reports to the Reserve, and it is recommended that the Reserve Livestock Calculation Tool be used for all calculations.

7.1 Project submittal documentation

Project developers provide the following information to the Reserve before registering reductions associated with the installation of a biogas control system.

- Completed project submittal form (see Appendix E)
- Signed attestation of title document
- Signed attestation of regulatory compliance
- Complete project verification report on an annual basis
- Positive verification opinion document

At a minimum, the above project documentation will be available to the public via the Reserve's online reporting tool – The Climate Action Reserve (Reserve).[43] Project developers will also have the option to make other documentation available for public viewing, such as the Reserve Livestock Calculation Tool.

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[43] Project Submittal forms and project registration information can be found at: http://www.climateactionreserve.org/how-it-works/projects/register-a-project/documents-and-forms/.

7.2 Record Keeping

For purposes of independent verification and historical documentation, project developers shall be required to keep all information outlined in this protocol for a period of 10 years after the information is generated or 7 years after the last verification.

System Information:

- All data inputs for the calculation of the baseline emissions and project emission reductions
- CO_2e annual tonnage calculations
- Relevant sections of the biogas control system operating permits
- Project developer attestation to compliance with regulatory requirements relating to the livestock project
- Project developer attestation that the livestock project was not undertaken to become compliant with any regulatory requirements
- Biogas control system information (installation dates, equipment list, etc.)
- Biogas flow meter information (model number, serial number, manufacturer's calibration procedures)
- Methane monitor information (model number, serial number, calibration procedures)
- Biogas flow data (for each flow meter)
- Biogas flow meter calibration data (for each flow meter)
- Biogas temperature and pressure readings (only if flow meter does not correct for temperature and pressure automatically)
- Methane concentration monitoring data
- Methane concentration monitor calibration data
- Destruction device monitoring data (for each destruction device)
- Destruction device, methane monitor and biogas flow monitor information (model numbers, serial numbers, calibration procedures)
- Initial and annual verification records and results
- All maintenance records relevant to the biogas control system, monitoring equipment, and destruction devices.

If using a calibrated portable gas analyzer for CH4 content measurement

- Date, time, and location of methane measurement
- Methane content of biogas (% by volume) for each measurement
- Methane measurement instrument type and serial number
- Date, time, and results of instrument calibration
- Corrective measures taken if instrument does not meet performance specifications

7.3 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. Although projects must be verified annually at a minimum, the Reserve will accept verified emission reduction reports on a sub-annual basis, should the project developer choose to have a sub-annual verification schedule (i.e. monthly, quarterly, etc.).

7.4 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 the year the biogas control system becomes operational. As described above, a system is operating if it is capturing and destroying methane gas from the treatment of the project developer's livestock waste.

7.5 Non-Climate Action Registry 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. In the event that GHG reductions from the project were previously registered with or claimed by another registry or program, or sold to a third party prior to submitting the project to the Reserve, a Project Transfer Form must be completed and submitted to the Reserve along with other project listing documentation. If the Registry determines that duplicative emissions reductions registration has occurred, all duplicate reductions reported with the Registry will be made void.

8 Glossary of Terms

Accredited verifier: A verification firm approved by the Reserve to provide verification services for project developers.

Additionality: Manure Management practices that are above and beyond business-as-usual operation, exceed the baseline characterization, and are not mandated by regulation.

Anaerobic: Pertaining to or caused by the absence of oxygen.

Anthropogenic Emissions: GHG emissions resultant from human activity that are considered to be an unnatural component of the Carbon Cycle (i.e. fossil fuel combustion, de-forestation etc.).

Biogas: The mixture of gas (largely methane) produced as a result of the anaerobic decomposition of livestock manure.

Biogas Control System (BCS): A system designed to capture and destroy the biogas that is produced by the anaerobic treatment and/or storage of livestock manure and/or other organic material. Commonly referred to as a "digester."

Biogenic CO_2 Emissions: CO_2 emissions resulting from the combustion and/or aerobic decomposition of organic matter. Biogenic emissions are considered to be a natural part of the carbon cycle, as opposed to anthropogenic emissions.

Carbon dioxide (CO_2): The most common of the six primary greenhouse gases, consisting of a single carbon atom and two oxygen atoms.

Clean development mechanism (CDM): One of the three flexible mechanisms established by the Kyoto Protocol. CDM is the market instrument in which certified emissions reductions can be achieved from a project developed in a "non-Annex I" country (developing country) with the assistance of an “Annex I” country (industrialized country). These reductions are accrued to the reduction commitment of the “Annex I” party (Art. 12 of the Kyoto Protocol) in the Kyoto Protocol’s first commitment period (2008-2012).

CO_2 Equivalent (CO_2e): The quantity of a given GHG multiplied by its total global warming potential. This is the standard unit for comparing the degree of warming which can be caused by different GHGs.

De minimis: Those emissions reported for a source or sources that are calculated using alternative methods selected by the operator, subject to the limits specified in this protocol.

Direct Emissions: Greenhouse gas emissions from sources that are owned or controlled by the reporting entity.

Emission factor: A unique value for determining an amount of a greenhouse gas emitted for a given quantity of activity data (e.g. metric tonnes of carbon dioxide emitted per barrel of fossil fuel burned.).

Flare: A destruction device that uses an open flame to burn combustible gases with combustion air provided by uncontrolled ambient air around the flame.

Fossil fuel: A fuel, such as coal, oil, and natural gas, produced by the decomposition of ancient (fossilized) plants and animals.

Greenhouse gas (GHG): means carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulfur hexafluoride (SF_6), hydrofluorocarbons (HFCs), or perfluorocarbons (PFCs).

Global Warming Potential (GWP): The ratio of radiative forcing (degree of warming to the atmosphere) that would result from the emission of one unit of a given GHG compared to one unit of CO_2.

Indirect Emissions: Emissions that are a consequence of the actions of a reporting entity, but are produced by sources owned or controlled by another entity.

Livestock Project: Installation of a Biogas Control System that, in operation, causes a decrease in GHG emissions from the baseline scenario through destruction of the methane component of biogas.

Metric tonne (MT) or “tonne”: A common international measurement for the quantity of GHG emissions, equivalent to about 2204.6 pounds or 1.1 short tons.

Methane (CH4): a potent GHG with a GWP of 21, consisting of a single carbon atom and four hydrogen atoms.

MMBtu: One million British thermal units.

Mobile combustion: Emissions from the transportation of materials, products, waste, and employees resulting from the combustion of fuels in company owned or controlled mobile combustion sources (e.g. cars, trucks, tractors, dozers, etc.).

Nitrous oxide (N_2O): a GHG consisting of two nitrogen atoms and a single oxygen atom.

Project Baseline: A business-as-usual GHG emission assessment against which GHG emission reductions from a specific GHG reduction activity are measured.

Project Developer: An entity that undertakes a project activity, as identified in the Livestock Project Protocol. A project developer may be an independent third party or the Dairy/Swine operating entity.

Stationary combustion source: A stationary source of emissions from the production of electricity, heat, or steam, resulting from combustion of fuels in boilers, furnaces, turbines, kilns, and other facility equipment.

van't Hoff-Arrhenius factor: The proportion of volatile solids that are biologically available for conversion to methane based on the monthly temperature of the system.[44]

Verification: The process used to ensure that a given participant's greenhouse gas emissions or emissions reductions have met the minimum quality standard and complied with the Reserve's procedures and protocols for calculating and reporting GHG emissions and emission reductions.

Verification body: A Reserve accredited firm that is able to render a verification opinion and provide verification services for operators subject to reporting under this protocol.

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[44] Mangino, et al.

9 References

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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.1 Livestock categories and Typical Average Mass (TAM)

Livestock category (L)	**Livestock Typical Average Mass (TAM) in kg**
Dairy cattle	
Dairy and non-milking dairy cows (on feed in intensive systems)	550[a]
Heifers (on feed in intensive systems)	415[b]
Bulls (grazing in large areas)	450[b]
Calves (semi-intensive with grazing or dual-purpose in extensive systems)	151[c]
Heifers (semi-intensive with grazing or dual-purpose in extensive systems)	300[c]
Cows (semi-intensive with grazing or dual-purpose in extensive systems)	425[c]
Swine	
Nursery swine	14.6[d]
Growing swine	40[d]
Finished swine	78[d]
Male swine	163[d]
Non-breeding swine	150[d]
Breeding swine	182[d]
Lactating breeding swine	191[d]

[a] Average animal mass of dairy cows in Mexico. Sources: FIRCO-SAGARPA, *Potencial de biogás en México*, México and SAGARPA, *Generación y Aprovechamiento de biogas en Granjas Porcinas y Establos Lecheros*, México.

[b] Default values for North America (feedlot cattle) and for Latin America (adult males). Source: IPCC, 2006. *IPCC Guidelines for National Greenhouse Gas Inventories*, Volumen 4, Chapter 10, Annex 10-A2. (Table 10A-2).

[c] Typical average animal mass at the national level: calves (0 – 1 year), heifers (average 1 – 3 years), cows (older than 3 years). Source: Ruiz-Suarez, L.G. and E. Gonzalez-Avalos, 1997, "Modeling methane emissions from cattle in Mexico" in *The Science of the Total Environment*, Elsevier, vol. 206, pp. 177-186 (Table 2).

[d] Consejo Mexicano de Porcicultura, 1997, *Manual para el manejo y control de aguas residuales y excretas porcinas en México*, project developed by E.P. Taiganides, R. Pérez-Espejo and E. Girón-Sánchez, México, D.F., México (Box 2.5).

Table B.2 Volatile Solids and Maximum Methane Potential by Livestock Category

Livestock category (L)	VS_L (kg/head/day)	$B_{o,L}$ (m^3 CH_4/kg VS)
Dairy cattle		
Dairy and non-milking dairy cows (in intensive systems in cool and temperate climate with an average annual temperature between 8°C and 23°C)	3.91[a]	0.188[b]
Dairy and non-milking dairy cows (in intensive systems in warm climate with an average annual temperature warmer than 24°C)	4.46[a]	0.188[b]
Heifers (intensive systems – feedlot cattle)	2.02[c]	0.17[c]
Bulls (grazing)	2.87[c]	0.10[c]
Calves and heifers (pasture or grazing in semi-intensive systems or dual-purpose)	2.14[c]	0.10[c]
Heifers (pasture or grazing in semi-intensive systems or dual-purpose)	2.14[c]	0.10[c]
Cows (grazing in semi-intensive systems in cold and temperate climate with an average annual temperature between 8°C and 23°C)	2.86[a]	0.10[c]
Dual-purpose cows (grazing in extensive systems in cold and temperate climate with an average annual temperature between 8°C and 23°C)	1.33[a]	0.10[c]
Dual-purpose cows (grazing in extensive systems in warm climate with an average annual temperature warmer than 24°C)	1.51[a]	0.10[c]
Swine		
Nursery swine	0.139[d]	0.48[e]
Growing swine	0.413[d]	0.48[e]
Finished swine	0.484[d]	0.48[e]
Male swine	0.272[d]	0.48[e]
Non-breeding swine	0.847[d]	0.48[e]
Breeding swine	0.405[d]	0.48[e]
Lactating breeding swine	1.139[d]	0.48[e]

[a] Estimations based on a study that examined laboratory measurements and chemical analyses of cattle manure in the Central region of Mexico (applicable for the entire country). The volatile solids values were estimated multiplying the fresh manure rate by the difference between the dry matter and ash content in the manure. Source: González-Ávalos, E. and L.G. Ruiz-Suárez, 2001. "Methane emission factors from cattle manure in Mexico" in *Bioresource Technology*, vol. 80, p. 63-71 (Table 2 – Chemical analyses of cattle manure - and Table 3 – Average daily fresh manure for various types of housing systems).

[b] González-Ávalos, E., 1999. *Determinación Experimental de los Factores de Emisión de Metano por Excretas de Bovino en México*, PhD thesis, Universidad Nacional Autónoma de México, México (page 76).

[c] Default values for North America (feedlot cattle) and for Latin America (adult males and young). Source: IPCC, 1996. *IPCC Guidelines for National Greenhouse Gas Inventories,* Chapter 4, Annex B (Table B-1)

[d] Estimations based on data of the software “PigMex” that uses excretion rate values for Mexico, VS values were calculated multiplying the total volatile solids (in kg TVS/100 kg. of animal live weight) by the typical animal mass for each swine animal category (from Table B.2). Source: Consejo Mexicano de Porcicultura, 1997, *Manual para el manejo y control de aguas residuales y excretas porcinas en México*, project developed by E.P. Taiganides, R. Pérez-Espejo and E. Girón-Sánchez, México, D.F., México (Box 3.9).

[e] Default values for North America. Source: IPCC, 2006. *IPCC Guidelines for National Greenhouse Gas Inventories*, Volumen 4, Chapter 10, Annex 10-A2. (Tables 10A-7 and 10A-8).

Table B.4: IPCC 2006 Methane Conversion Factors by Manure Management System Component/Methane Source ‘S’ [45]

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.

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[45] 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.

Table B.3 Emission Factor for Stationary and Mobile Combustion

Fuel	Emisión Factors [kg CO_2/GJ]
Stationary Combustion [a]	
Crude oil	73.30
Natural gas liquids	64.20
Gasoline	69.30
Kerosene	71.90
Diesel	74.10
Residual fuel oil	77.40
Liquified Petroleum Gas (LPG)	63.10
Naphtha	73.30
Lubricants	73.30
Petroleum coke	97.50
Coking coal	94.60
Bituminous coal	94.60
Sub-bituminous coal	96.10
Natural gas	56.10
Waste oils	73.30
Mobile combustion [b]	
Gasoline passenger car (without catalyst – Before 1990)	58.07
Gasoline passenger car (with oxidation 2-way catalyst – 1991-1992)	66.82
Gasoline passenger car (with used 3-way catalyst – open or closed cycle – 1993 – 1997)	70.07
Gasoline passenger car (with new 3-way closed cycle catalyst – After 1998)	71.07
Gasoline light duty trucks (without catalyst – Before 1990)	57.07
Gasoline light duty trucks (with improved technology, without catalyst – 1991-1992)	60.82
Gasoline light duty trucks (with used 3-way catalyst – open or closed cycle – 1993-1997)	68.97
Gasoline light duty trucks (with new 3-way catalyst – After 1998)	70.52
Gasoline heavy duty trucks and buses (without catalyst – Before 1992)	55.56
Gasoline heavy duty trucks and buses (with catalyst – After 1993)	60.87
Diesel vehicles (passenger cars, light and heavy trucks – with or without emissions control)	72.10
LPG vehicles (passenger cars and heavy trucks – without control and with 3-way catalyst)	61.23
Natural gas vehicles (passenger cars and heavy trucks – with 3-way catalyst)	56.10
Motorcycles (with or without emissions control)	72.10
Compressed natural gas vehicles (CNG) [c]	56.10
Liquefied natural gas vehicles (LNG) [c]	56.10
Airplanes (jetfuel) [c]	71.90

[a] IPCC, 2006. *IPCC Guidelines for National Greenhouse Gas Inventories*, Volumen 2, Chapter 2, Stationary Combustion, Table 2.5, pages 2.22-2.23.

[b] INE, 2005. Inventario Nacional de Emisiones de Gases de Efecto Invernadero 2002, Sector Transporte. INE-SEMARNAT, México. (Annexes, Tables 4-12, pages IA3-95 – IA3-99). Available on line: http://www.ine.gob.mx/cclimatico/inventario3.html

[c] IPCC, 2006. *IPCC Guidelines for National Greenhouse Gas Inventories*, Volumen 2, Chapter 3, Mobile combustion, Table 3.2.1, pages 3.16.

Table B.4 Fossil fuels net calorific values

Fuel	Net calorific value
Solid fuels	
National thermal coal	19.405 GJ/metric tonne
National metallurgic coal	23.483 GJ/metric tonne
Petroleum coke	31.424 GJ/metric tonne
Coking coal	26.521 GJ/metric tonne
Liquid fuels [a]	
Crude oil	0.03871 GJ/liter
Gasoline	0.03161 GJ/liter
Kerosene	0.03381 GJ/liter
Diesel	0.03555 GJ/liter
Residual fuel oil	0.03944 GJ/liter
Liquefied Petroleum Gas (LPG) [b]	0.02627 GJ/liter
Naphtha	0.03161 GJ/liter
Lubricants	0.03888 GJ/liter
Gaseous fuels	
Natural gas [c]	0.03391 GJ/m^3

[a] 1 barrel = 158.9873 liters

[b] Fuel obtained from oil distillation and after processing the natural gas liquids. It mainly consists on propane, butane or a mixture of both. It is mainly used in the residential and commercial sectors as well as in vehicles for passenger and freight transportation.

[c] Found as "gas seco" in the Energy National Balance, which corresponds to the gaseous hydrocarbon obtained as a by-product in the natural gas processing plants and refineries after liquefied by-products has been extracted. This fuel is used in the residential, commercial, industrial, agriculture and public sectors as well as in power plants.

Sources:
SENER, 2006. *Balance Nacional de Energía 2007*, Dirección General de Información y Estudios Energéticos, SENER, México. Box 21, page 100. Available at: http://www.energia.gob.mx/webSener/res/PE_y_DT/pub/Balance_2007.pdf (March 2009)

Appendix C – Summary of the Performance Standard Analysis

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 Mexican 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 Mexico,
- GHG emissions from livestock manure management,
- Data on livestock manure management practices in Mexico,
- Mexican environmental regulations impacting manure management practices,
- Recommendation for a performance threshold for livestock operations.

C.1 Data of livestock operations in Mexico

According to the 2007-2012 National Livestock Program and to the SIAP (Agricultural, Livestock, Food and Fisheries Information System) of the Ministry of Agriculture, Livestock, Rural Development, Fisheries and Food (SAGARPA), the beef cattle has a population of approximately 28.9 million heads at nearly a million production units. [46] This activity is carried out mainly in extensive grazing production systems, covering more than 50% of the national territory. However, nearly 2.5 million head (8.7% of the total population) is raised in fattening/growing corrals, mainly in the arid and semi-arid northern regions of the country.

The total dairy herd had population of around 2.2 million head in 2005.[47] The states that concentrate around the 70% of the dairy cattle are: the Lagunera Region (Coahuila and Durango) (24.1%), Chihuahua (9.9%), Jalisco (9.8%), Hidalgo (8.5%), Puebla (7.9%) and Guanajuato (7.4%). Nearly 50.6% of milk production originates from specialized intensive farms; 21.3% from semi-intensive systems, 18.3% of double purpose systems and 9.8% of small back-yard farms.[48]

Swine operations had a population of around 15.2 million hogs in 2005. Almost 50% of swine population concentrates in the states of Jalisco (15.1%), Sonora (8.4%), Puebla

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[46] Available on line: www.sagarpa.gob.mx/ganaderia/PNP/PNP260907.pdf and http://www.siap.sagarpa.gob.mx/ (March 2009)

[47] SIAP data from SAGARPA. Available on line: http://www.siap.sagarpa.gob.mx/ (March 2009)

[48] Gallardo-Nieto, JL. 2005. *Situación actual de la producción de leche de bovino en México 2004*. Coordinación General de Ganadería, SAGARPA, México.

(8.0%), Veracruz (7.2%), Guanajuato (6.7%) and Yucatán (6.5%),[49] 43.6% of this population is located in 4,286 specialized and semi-specialized farms, while the remaining 56.4% is located in more than 1.5 million small back-yard family farms.

Table C.1 illustrates the livestock population in Mexico and its possible distribution according their production systems.

Table C.1. Livestock population data for Mexico, 2005

	Total population[a] [head]	Extensive grazing or back-yard livestock operations		Modern and semi-modern intensive livestock operations	
		Population [head]	Production units [farms]	Population [head]	Production units [farm]
Beef cattle	28,836,622	23,366,622	n.a.	2,500,000[b]	n.a.
Dairy cattle	2,197,346	617,454[e]	n.a.	1,579,892[e]	3,000[c,d]
Swine	15,206,310	5,473,520[c]	1,501,672[c]	6,635,988[c]	4,286[c]

n.a. not available

[a] Sistema de Información Agrícola y Pecuaria (SIAP) http://www.siap.sagarpa.gob.mx/ (March 2009)

[b] SAGARPA, 2008. *Programa Nacional Pecuario 2007-2012,* SAGARPA, Mexico. http://www.sagarpa.gob.mx (March 2009)

[c] FIRCO-SAGARPA, *Potencial de biogás en México*. México.

[d] Dairy farms with herds greater than 100 head.

[e] Own estimations assuming that 50.6% of dairy cattle is in specialized farms, 21.3% in semi-specialized, 18.3% in double-purspose systems and 9.8% in back-yard farms.

C.2 Analysis of common practices of the manure management systems in Mexico

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.

Because national level data for livestock manure management systems were not available, the analysis was conducted based on publications and data provided by Mexican institutions such as SAGARPA, FIRCO, reports, academic papers, and CDM project design documents related to dairy cattle and swine operations.

Swine operations

According to data set provided by the Coordination of Livestock of the SAGARPA, there are 4,286 specialized and semi-modern farms with an approximate population of 6.6 million hogs. At the national level, 62% of these farms have small (from 1 to 100 heads) or medium-size herds (from 101 to 500 heads), while 38% of the farms have herds greater than 500 hogs. Small and medium semi-modern swine operations are predominant in states like Jalisco, Michoacán and Guanajuato. Although some of these farms may have modern technologies, several of them continue employing traditional manure management systems, such as liquid slurry, solid storage, composting and liquid treatment systems (complete lagoons systems, sedimentation lagoons and

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[49] SIAP data from SAGARPA. Available on line: http://www.siap.sagarpa.gob.mx/ (March 2009)

sedimentation and oxidation ponds).[50] On the other hand, intensive modern swine operations with herds greater than 2,000 hogs are mainly located in Sonora, Yucatán, Nuevo León and Sinaloa.

A study conducted by the National Autonomous University of Mexico (UNAM) and SEMARNAT examined the relation between farm size and manure treatment systems, among others variables, in order to analyze the cost-benefit of the NOM-001 in the quality of wastewater in swine farms. [51] In this study, the farm size is defined according to the organic load of the wastewater discharge based on the quantity of total suspended solids (TSS) as well as to the compliance dates of the norm as follows:

- Large swine operations that have the compliance date as of January 1, 2000 and with a wastewater generation with more than 3 tonnes per day of TSS are those with an approximate number of 833 “sows” [52] (around 8,330 hogs);
- Medium-sized operations having the compliance date as of January 1, 2005 and with a wastewater generation with 1.2 to 3 tonnes of TSS have between 333 and 833 “sows” (around 3,330 and 8,330 hogs); and
- Small-sized operations having the compliance date as of January 1, 2010 and with a wastewater generation with less than 1.2 tonnes of TSS with a herd smaller than 3,330 hogs.

According to this classification and to the database provided by SAGARPA, there are around 165 large farms (3.8% of the 4,286 formal farms) that concentrate around 40.6% swine population in these farms; 430 medium-sized farms (10% of the formal farms) with 32.2% of the population, and the 86.1% of the remaining farms (3,691 farms) are small-sized farms with 27.2% of the population.

In theory, large and medium-sized farms that discharge to water bodies would require tertiary treatment systems, which usually include a lagoon when using a biological process, to comply with the maximum contamination limits established in the NOM-001. In practice, there are not enough data or studies available to assure this, neither the degree of compliance with the standard. However, the above mentioned study describes that several of the analyzed farms had different types of treatment systems. In addition, experts coincide that modern and semi-modern swine farms generally have lagoon-based treatment systems. [53]

On the other hand, 69 CDM projects related to manure management in swine operations (registered in the CDM Executive Board by February 2009) were examined. These projects provide information of around 430 farms with a total population of 2.2 million hogs, where 73% of these farms have herds greater than 2,000 heads. According to these projects, the most common manure collection techniques are: scrapper, pull &

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[50] Steinfeld, H., H. Menzi, P. Gerber, M. Sánchez, S. Gómez, G. Barrera, J.A. Espinosa, G. Salazar, J.G. Martínez, G. Mariscal, P. Jurado, J. González, R. Pérez-Espejo, 2003. *Reporte de la Iniciativa de la Ganadería, el Medio Ambiente y el Desarrollo (LEAD) - Integración por Zonas de la Ganadería y de la Agricultura Especializadas (AWI) - Opciones para el Manejo de Efluentes de Granjas Porcícolas de la Zona Centro de México*. FAO, Roma, Italia. http://www.fao.org/WAIRDOCS/LEAD/X6372S/X6372S00.HTM

[51] Pérez-Espejo, R., 2006. *Granjas porcinas y medio ambiente, Contaminación del agua en La Piedad, Michoacán*, Plaza y Valdés Editores, México, pp. 201. (Box 8, page 101)

[52] One “sow” is defined as a breeding swine with an approximate weight of 180 kg. that can give birth to 8 to 12 litters. Under this definition, an approximation of 10 hogs per sow is used.

[53] Experts’ opinion: personal communication with staff from the Electrical Research Institute (IIE by its Spanish acronym) and Colegio de la Frontera Norte (April 15, 2009).

plug, flush, pumping or a combination of them. As to manure treatment and storage methods, 95.8% of the farms reported to have open lagoons systems; 0.5%, use earthen basins, and the 2.6% reported to flush the manure from the barns draining to concrete canals and subsequently discharged into agricultural canals.

Based on the examined CDM projects, academic papers and experts' opinion, it can be considered that treatment lagoon systems are the common practice in intensive systems at large and medium-sized modern and semi-modern swine farms. In addition, it is mentioned that open lagoon systems is the prevailing practice in Mexico due to the fact that it is the least expensive manure treatment which meets the requirements of local, state and federal wastewater legislation.

Dairy cattle
According to González-Ávalos and Ruiz-Suárez (2007),[54] anaerobic lagoons and slurry manure management systems are more likely to benefit milk production under intensive systems (50.6% of national milk production). Semi-intensive and dual-purpose production systems (31.1% of milk production) may use dry lot or solid storage systems where manure is stored for spreading later in agricultural fields as fertilizer.

In Mexico, there are around 3,000 dairy farms with herds greater than 100 head.[55] Although the most common herd size for large modern farms is between 100 and 500 head, the general trend in Mexico is toward total confinement production systems with increasingly large herds.[56] In the Lagunera Region (Coahuila and Durango) and Chihuahua, intensive operations with herds between 2,000 and 6,000 head can be found.

Seventeen CDM projects related to manure management in dairy farms (registered in the CDM Executive Board by February 2009) were examined. These projects provide information of 34 farms with a total population of 63,649 dairy cows. The herd size of these farms varied from 300 and 5,295 head. The most common collection techniques from corrals, milking parlors and holding areas were the use of scrapers, tractors and vacuum in 44% of the farms, while 41% of the farms mixed water with manure waste to flush it into the storage facilities. As to manure treatment and storage methods, 65% of the farms reported to have open lagoons systems; while the remaining 35% did not specify their current manure storage method, some of them stated to have anaerobic lagoons under construction or under planning. Based on the examined CDM projects and experts' opinion, it can be considered that open lagoon systems are the common practice in modern and semi-modern intensive dairy farms that have manure treatment systems. [57]

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[54] González Ávalos, E. and L.G. Ruiz-Suárez, 2007. "Methane conversion factors from cattle manure in Mexico" in *Atmósfera*, vol. 20, no. 1, p. 83-92.

[55] FIRCO-SAGARPA, *Potencial de biogás en México*. México.

[56] Speir, J., M.A. Bowden, D. Ervin, J. McElfish, R. Pérez-Espejo, T. Whitehouse, C. Line Carpenter, 2003. *Comparative Standards for Intensive Livestock Operations in Canada, Mexico, and the United States*, Report prepared for the Commission of Environmental Cooperation. Available: http://www.cec.org/files/PDF/ECONOMY/Speir-etal_es.pdf

[57] Experts' opinion: personal communication with staff of the Electrical Research Institute and Colegio de la Frontera Norte (April 15, 2009).

C.3 Current digesters use in Mexico

Since the entry into force of the Kyoto Protocol in 2005 and the full operation of the CDM, methane recovery in large-scale swine farms has rapidly gained importance. Up to February 2009, around 69 swine breeding projects and 17 dairy operation projects for methane emissions reduction has been registered in the CDM Executive Board. Table C.2 illustrates the implementation of 431 digesters in different states through these CDM projects. In the case of swine farms, it was estimated that around 90% of the digesters mentioned in the CDM project design documents were actually implemented. [58]

Tabla C.2. Number of digesters implemented in swine and dairy farms through CDM projects

State	Total modern and semi-modern swine farms by state [farms][a]	Number of digesters in swine farms[b]	Number of digesters in dairy farms [b]
Sonora	344	146	0
Jalisco	1,352	102	0
Puebla	74	43	0
Veracruz	90	31	0
Tamaulipas	25	13	0
Yucatán	219	16	0
Nuevo León	142	12	0
Guanajuato	917	9	2
Sinaloa	26	6	0
Michoacán	357	4	0
Querétaro	60	4	0
Aguascalientes	26	4	2
Chiapas	80	3	0
Hidalgo	103	2	0
Estado de México	46	2	0
Durango	27	1	8
Coahuila	23	1	16
San Luis Potosí	17	1	0
Baja California	7	0	2
Chihuahua	1	0	1
Total	3,936	400	31

[a] Data set provided by the Livestock Coordination of SAGARPA

[b] Estimation based on CDM Project design documents, available on line: http://cdm.unfccc.int/Projects/registered.html (February 2009)

C.4 Performance Standard Recommendation

The Performance Standard recommended is a technology-specific threshold that dairy or swine operators would meet. The threshold should be the installation of a biogas control system (anaerobic digester).

With regard to swine operations, 43.6% of the total swine population is located in 4,286 specialized and semi-specialized farms, while the remaining 56.4% is located in small

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[58] Experts' opinion: personal communication with staff of the Mexican Swine Confederation and an independent consultant (April 22 and May 11, 2009 respectively).

back-yard farms. The anaerobic digesters implemented and operating in 430 farms through CDM projects represent around 10% of all the formal farms, implying that around 3,716 modern and semi-modern farms may not have installed anaerobic digesters. Despite the fact that the farms operating digesters in certain states represent a significant percentage of their number of formal modern farms (for example, 47% of the farms in Puebla; 40% in Sonora; and 31% in Veracruz), the installation and use of digesters in swine operations is not a prevailing practice due to the following institutional, technological and financial barriers:[59]

Institutional Barriers

- Lack of environmental laws related to livestock operations and the low enforcement of existing ones.
- Weak national institutional capabilities to design and manage projects to reduce methane emissions derived from the livestock activity.
- Without some kind of government guarantee or incentive, local commercial banks are not usually interested in financing the acquisition of anaerobic digesters, primarily because of lack of knowledge and experience with the technology.

Technological Barriers

- Large heterogeneity among the livestock production units in relation to their size and use of technology.
- High investment costs, engineering services, operational and maintenance costs.
- These systems become progressively more expensive on a ‘per animal’ basis as farm size decreases.
- Lack of comprehensive schemes to address the issue of livestock waste.
- There is not a consolidated industry currently producing digesters on regular and systematic basis at a national level. It is necessary to import relevant digester components, such as covers and geo-membranes as well as monitoring instruments and enclosed flares.

Economic Barriers

- Uncertainty with regards to profitability levels for the livestock producers.
- There are not enough public and private funding schemes.
- Critical economic situation of national breeders due to international prices. This makes it difficult for them to invest in waste treatment.
- Odour benefits, potential water quality enhancements, and the incremental savings associated with heating cost avoidance, are rarely enough to compel farmers to upgrade to an anaerobic digestion system

Socio-cultural Barriers

- Low local capacity (qualified personnel) to construct, operate and/or maintain anaerobic digesters.
- Cultural change of the farm operators is required in order that their farm cleaning practices as well as the animals’ feeding do not affect the methane-producing bacteria population.

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[59] SEMARNAT, 2008. *Methane to Markets, Mexico Profile, Animal Waste Management Methane Emissions*, México. Available on line: http://www.methanetomarkets.org/resources/ag/docs/mexico_profile.pdf

With regard to dairy operations, the 31 digesters installed in these operations through CDM projects is low (around 1%) compared to number of estimated 3,000 production units greater than 100 dairy cows. In a similar manner to the case of swine operations, the main barrier inhibiting the installation and use of digesters is cost. According to a case study in the Delicias, Chihuahua, region, the installation cost of a digester can vary between $1,512,614 and $1,589,297 Mexican pesos for dairy cattle between 200 and 2,000 head respectively.[60]

It is important to note that although some municipalities recommend the use of particular manure management systems, the installation of anaerobic digesters is not mandatory in any of these municipalities.

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[60] Casas, M., B.A. Rivas, M. Soto, A. Segovia, H.A. Morales, M.I. Cuevas, C.M. Keissling, 2009. "Estudio de Factibilidad para la puesta en marcha de digestores anaeróbicos en establos lecheros en la Cuenca de Delicias, Chihuahua" in *Revista Mexicana de Agronegocios*, volumen 24, Universidad Autónoma de la Laguna, México, p. 745-756.

Appendix D – Data Substitution and Failed Calibration

This appendix provides guidance on calculating emission reductions when data integrity has been compromised either due to missing data points or a failed calibration. No data substitution is permissible for equipment such as thermocouples which monitor the proper functioning of destruction devices. Rather, the methodologies presented below are to be used only for the methane concentration and flow metering parameters.

Failed Calibration

If any device fails a calibration test (i.e., tested to be outside of the allowable 5% margin of error), the following guidance must be followed. These adjustments must be made for the entire period from the last successful calibration until such time as the meter is properly calibrated.

1. For calibrations that indicate underreporting (lower flow rates, or lower methane concentration):
    a. the metered values must be used without correction.

2. For calibrations that indicate over-reporting (higher flow rates, or higher methane concentration):
    a. the metered values must be adjusted based on the greatest calibration drift recorded at the time of calibration.

Missing Data

The Reserve expects that projects will have continuous, uninterrupted data for the entire verification period. However, the Reserve recognizes that unexpected events or occurrences may result in brief data gaps.

The following data substitution methodology may be used only for flow and methane concentration data gaps that are discrete, limited, non-chronic, and due to unforeseen circumstances. Data substitution can only be applied to methane concentration *or* flow readings, but not both simultaneously. If data is missing for both parameters, no reductions can be credited.

Further, substitution may only occur when two other monitored parameters corroborate proper functioning of the destruction device and system operation within normal ranges. These two parameters must be demonstrated as follows:

1. Proper functioning can be evidenced by thermocouple readings for flares, energy output for engines, etc.
2. For methane concentration substitution, flow rates during the data gap must be consistent with normal operation.
3. For flow substitution, methane concentration rates during the data gap must be consistent with normal operations.

If corroborating parameters fail to demonstrate any of these requirements, no substitution may be employed. If the requirements above can be met, the following substitution methodology maybe applied:

Duration of Missing Data	Substitution Methodology
Less than six hours	Use the average of the four hours immediately before and following the outage
Six to 24 hours	Use the 90% lower or upper confidence limit of the 24 hours prior to and after the outage, whichever results in greater conservativeness.
One to seven days	Use the 95% lower or upper confidence limit of the 72 hours prior to and after the outage, whichever results in greater conservativeness.
Greater than one week	No data may be substituted and no credits may be generated

For livestock projects, both the lower and upper limit must be utilized. For calculating fugitive emissions from the gas management system ($PE_{CH4,BCS}$), the upper limit should be used. However, for calculating combusted gas ($CH_{4,destroyed}$), the lower limit must be applied[61].

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[61] When using the livestock calculation tool, only one value for methane flow can be entered, and is automatically populated into $PE_{CH4,BCS}$ and $CH_{4,destroyed}$. The *higher* values should be input initially, as this is conservative of the project emissions calculations. However, if the comparison of modeled to measured emissions indicates that reductions will be based off of monitored emissions, then the *lower* value must be substituted and used, as this will result in conservativeness.