July 2011

California Environmental Protection Agency

AIR RESOURCES BOARD

Compliance Offset Protocol ~~for~~ Livestock ~~Manure (Digester)~~ Projects

Capturing and Destroying Methane from Manure Management Systems

Adopted: [INSERT Date of Board Adoption]

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Abbreviations and Acronyms

ARB	California Air Resources Board
BCS	Biogas control system
BDE	Biogas destruction efficiency
CAR	Climate Action Reserve
CH_4	Methane
CNG	Condensed natural gas
CO_2	Carbon dioxide
EPA	U.S. Environmental Protection Agency
GHG	Greenhouse gas
GWP	Global Warming Potential
IPCC	Intergovernmental Panel on Climate Change
lb	Pound
LNG	Liquefied natural gas
MS	Management system
MT or t	Metric ton ~~or tonne~~
N_2O	Nitrous oxide
NG	Natural gas
QA/QC	Quality Assurance/Quality Control
Regulation	Regulation, title 17, California Code of Regulations, sections 95800 et seq.
scf	Standard cubic foot
SSR	Source, sink, and reservoirs
STP	Standard temperature and pressure

~~t~~	~~Metric ton or tonne~~
TAM	Typical average mass
VS	Volatile solids

1 Introduction

The Compliance Offset Protocol ~~for~~ Livestock ~~Manure (Digester)~~ Projects provides methods to quantify and report greenhouse gas (GHG) emission reductions associated with the installation of a biogas control system (BCS) for manure management on 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 protocol is based on the Climate Action Reserve's Livestock Project Protocol Version 2.2[1] and includes some clarifications and updates from~~proposed in the draft~~ Version 3.0.[2]~~.~~

Offset Project Operators or Authorized Project Designees that install manure biogas capture and destruction technologies use the methods contained in this protocol~~document~~ to quantify and report GHGs. The protocol provides eligibility rules, methods to quantify GHG reductions, offset project-monitoring instructions, and procedures for preparing~~reporting~~ ~~o~~Offset ~~p~~Project ~~d~~Data ~~r~~Reports. Additionally, all offset projects must submit to annual, independent verification by ARB-accredited verification bodies. Requirements for verification bodies to verify ~~o~~Offset ~~p~~Project ~~emissions d~~Data ~~r~~Reports are provided in the Cap and Trade Regulation (Regulation).

This protocol is designed to ensure the complete, consistent, transparent, accurate, and conservative quantification of GHG emission reductions associated with a livestock digester project. The protocol is comprised of both quantification methodologies and regulatory program requirements to develop a livestock project and generate ~~compliance~~ARB or registry offset credits.

AB 32 exempts quantification methodologies from the Administrative Procedure Act (APA)[3], however those elements of the protocol are still regulatory. The exemption allows future updates to the quantification methodologies to be made through a public review and Board adoption process but without the need for rulemaking documents. Each protocol identifies sections that are considered quantification and exempt from APA requirements. Any changes to the non-quantification elements of the offset protocols would be considered a regulatory update subject to the full regulatory development process. Those sections that are considered to be a quantification methodology are clearly indicated in the title of the chapter or subchapter if only a portion of that chapter is considered part of the quantification methodology of the protocol.

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[1] Climate Action Reserve~~CAR~~ (2009) Livestock Project Protocol Version 2.2. November 3, 2009. http://www.climateactionreserve.org/wp-content/uploads/2009/03/Livestock-Project-Protocol-Version2.2.pdf (accessed November 3, 2009)

[2] Climate Action Reserve~~CAR~~ (2010) ~~Draft~~ Livestock Project Protocol Version 3.0. September 29~~July 27~~, 2010.] http://www.climateactionreserve.org/wp-content/uploads/2009/03/U.S._Livestock_Project_Protocol_V3.02.pdf ~~http://www.climateactionreserve.org/wpcontent/uploads/2010/07/DRAFT_Livestock_Project_Protocol_V3_072710.pdf~~ (accessed September 29~~July 27~~, 2010)

[3] Health and Safety Code section 38571

2 The GHG Reduction Project

2.1 Background

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 anaerobic 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 methane production.

2.2 Project Definition – Quantification Methodology

For ~~the~~ purposes of this protocol, ~~the GHG reduction~~offset project is defined as the installation of a biogas control system that captures and destroys methane gas from anaerobic manure treatment and/or storage facilities on livestock operations.[4] The biogas control system must destroy methane gas that would otherwise have been emitted to the atmosphere in the absence of the offset project from uncontrolled anaerobic treatment and/or storage of manure.[5]

Captured biogas can 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 ~~offset project operators or authorized project designees take advantage of~~ the ~~captured~~ biogas is utilized, the ultimate fate of the methane must be destruction.

"Centralized digesters" that integrate waste from more than one livestock operation may also meet the definition of an offset project.[6]

2.3 ~~The~~ Offset Project Operator or Authorized Project Designee

The ~~o~~Offset ~~p~~Project ~~o~~Operator or ~~a~~Authorized ~~p~~Project ~~d~~Designee is responsible for project listing, monitoring, reporting and verification. The ~~o~~Offset ~~p~~Project ~~o~~Operator or ~~a~~Authorized ~~p~~Project ~~d~~Designee must submit the information in the Regulation and in Appendix C of this protocol ~~to meet the listing requirements in the Regulation~~. The Offset Project Operator or Authorized Project Designee must have legal authority to implement the offset project.

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[4] 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.

[5] The installation of a BCS at an existing livestock operation where the primary manure management system is aerobic (produces little to no methane) may result in an increase of the amount of methane emitted to the atmosphere. Thus, the BCS must digest manure that would primarily be treated in an anaerobic system in the absence of the project in order for the project to meet the definition of an offset project.

[6] The protocol ~~also~~ does not preclude Offset ~~p~~Project ~~o~~Operators or Authorized Project Designees from co-digesting organic matter in the biogas control system. However, the additional organics could impact the nutrient properties of digester effluent, which Offset ~~p~~Project ~~o~~Operators or Authorized Project Designees should consider when assessing the offset project's associated water quality impacts.

3 Eligibility Rules

Offset ~~P~~projects that~~must~~ meet the project definition and requirements in section 2.2~~of an offset project and~~ must fully satisfy the eligibility requirements ~~rules~~ in the Regulation ~~in order to receive an offset credit~~ in addition to the eligibility rules listed below to be eligible to receive ARB or registry offset credits.

3.1 Location

Only projects located in the United States and its territories~~, or on U.S. tribal lands,~~ are eligible ~~to create compliance offset credits~~ under this protocol. In addition, offset projects situated on the following categories of land are only eligible under this protocol if they meet the requirements of this protocol and the Regulation, including the waiver of sovereign immunity requirements of section 95975(l) of the Regulation:

1. Land that is owned by, or subject to an ownership or possessory interest of a Tribe;
2. Land that is “Indian lands” of a Tribe, as defined by 25 U.S.C. §81(a)(1); or
3. Land that is owned by any person, entity, or Tribe, within the external borders of such Indian lands.

3.2 Offset Project Commencement

For this protocol, Offset~~The~~ ~~p~~Project ~~c~~Commencement is defined as the date at which the offset project’s biogas control system (BCS) becomes operational. ~~For the purposes of this protocol, a~~A BCS is considered *operational* on the date at which the system begins producing and destroying methane gas upon completion of an initial start-up period. ~~Projects with commencement dates prior to December 31, 2006 are not eligible under this protocol.~~ Offset ~~P~~projects may always be submitted for listing prior to their commencement date.

3.3 Project Crediting Period

~~Offset project operators or authorized project designees are eligible to create GHG reductions for compliance offsets according to~~The crediting period for this protocol ~~for a period of~~is ten years. ~~following the project’s commencement date.~~

~~3.4 Anaerobic Baseline - Quantification Methodology~~

~~Offset project operators or authorized project designees must demonstrate that the depth of the anaerobic lagoons or ponds prior to the project’s implementation were sufficient to prevent algal oxygen production and create an oxygen-free bottom layer; which means at least 1 meter in depth.~~

~~Greenfield livestock projects (i.e., projects that are implemented at new livestock facilities that have no prior manure management system) are eligible only if the offset project operator or authorized project designee can demonstrate that uncontrolled anaerobic storage and/or treatment of manure is common practice in the industry and geographic region where the project is located.~~

3.4 ~~3.5~~ Additionality

~~The protocol~~Offset projects must meet the additionality requirements in the Regulation in addition to the requirements below. ~~In summary, the activity must not be required by or undertaken to comply with any federal, state, local law or ordinance, or other legally binding mandates in the project's jurisdiction.~~

3.4.1 Anaerobic Baseline - Quantification Methodology

The ~~o~~Offset ~~p~~Project ~~o~~Operator or ~~a~~Authorized ~~p~~Project ~~d~~Designee must demonstrate that the depth of the anaerobic lagoons or ponds prior to the offset project's implementation were sufficient to prevent algal oxygen production and create an oxygen-free bottom layer; which means at least 1 meter in depth.

Greenfield livestock projects (i.e., projects that are implemented at new livestock facilities that have no prior manure management system) are eligible only if the ~~o~~Offset ~~p~~Project ~~o~~Operator or ~~a~~Authorized ~~p~~Project ~~d~~Designee can demonstrate that uncontrolled anaerobic storage and/or treatment of manure is common practice in the industry and geographic region where the offset project is located.

3.5~~6~~ Regulatory Compliance

As stated in the Regulation, an ~~o~~Offset ~~p~~Project ~~o~~Operator~~s~~ or ~~a~~Authorized ~~p~~Project ~~d~~Designees must fulfill all applicable local, regional and national requirements on environment impact assessments that apply based on the offset project location. Offset ~~P~~projects must also ~~meet any other~~fulfill all local, regional, and national regulatory requirements that ~~might~~ apply based on the offset project location. Offset ~~P~~projects are not eligible to receive ARB or registry offset credits for GHG reductions or GHG removal enhancements that ~~occur as the result of collection or destruction activities~~ are not in compliance with regulatory requirements.

4 ~~The GHG Assessment~~ Offset Project Boundary – Quantification Methodology

The ~~GHG Assessment~~Offset Project Boundary delineates the GHG sources, GHG sinks, and GHG reservoirs (SSRs) that shall be assessed ~~by offset project operators or authorized project designees~~ to determine the net change in emissions associated with installing a BCS. For ~~T~~this protocol~~'s~~ the Offset Project ~~assessment b~~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 Offset Project ~~b~~Boundary they are not assessed in the calculation procedure.

This protocol does not account for carbon dioxide emission reductions associated with displacing grid-delivered electricity or fossil fuel use.

~~CO_2 emissions associated with the generation and destruction of biogas are considered biogenic emissions[7] (as opposed to anthropogenic) and are not included in the GHG Assessment Boundary.~~

Figure 4.1 provides a general illustration of the ~~GHG Assessment~~Offset Project Boundary, indicating which SSRs are included or excluded from the Offset Project ~~b~~Boundary. All SSRs within the dashed line are accounted for under this protocol.

Table 4.1 provides greater detail on each SSR and information for the SSRs and gases from the ~~GHG Assessment~~Offset Project Boundary.

~~[7] 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.~~

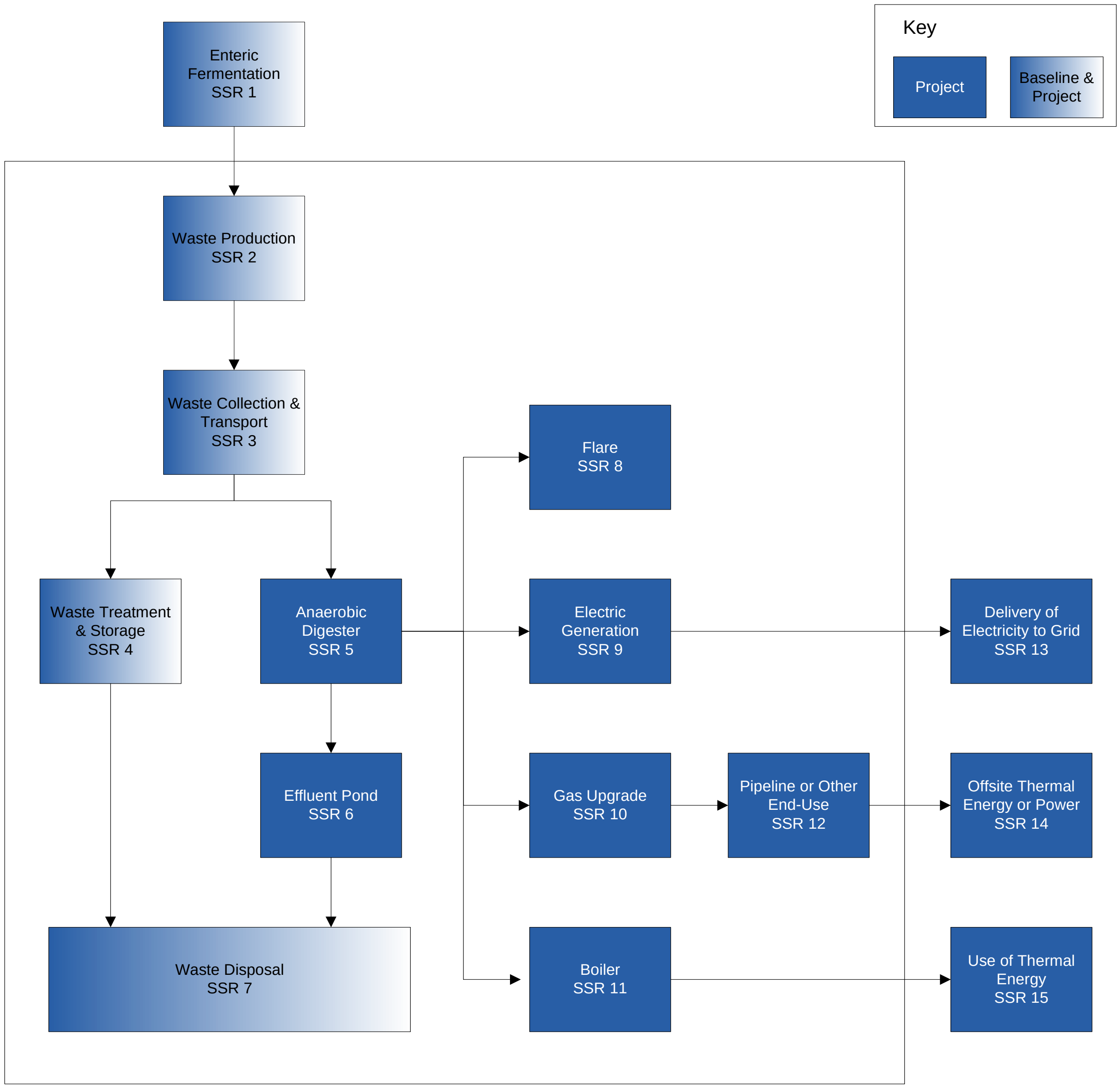


Figure 4.1. General Illustration of the ~~GHG Assessment~~ Offset Project Boundary

Table 4.1 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.

Table 4.1. Description of all GHG Sources, GHG Sinks, and GHG Reservoirs

SSR	GHG Source	Gas	Relevant to Project Baseline (B) or Offset Project (P)	Included/ Excluded
1	Emissions from enteric fermentation	CH_4	B, P	*Excluded*
2	Emissions from waste deposits in barn, milking parlor, or pasture/corral	N_2O	B, P	*Excluded*
	Emissions from mobile and stationary support equipment	CO_2	B, P	*Included*
		CH_4		*Excluded*
		N_2O		*Excluded*
3	Emissions from mechanical systems used to collect and transport waste (e.g. engines and pumps for flush systems; vacuums and tractors for scrape systems)	CO_2	B, P	*Included*
		CH_4		*Excluded*
		N_2O		*Excluded*
	Vehicle emissions (e.g. for centralized digesters)	CO_2		*Included*
		CH_4		*Excluded*
		N_2O		*Excluded*
4	Emissions from waste treatment and storage including: anaerobic lagoons, dry lot deposits, compost piles, solid storage piles, manure settling basins, aerobic treatment, storage ponds, etc.	CO_2	B, P	*Excluded*
		CH_4		*Included*
		N_2O		*Excluded*
	Emissions from support equipment	CO_2		*Included*
		CH_4		*Excluded*
		N_2O		*Excluded*
5	Emissions from the anaerobic digester due to biogas collection inefficiencies and venting events	CH_4	P	*Included*
6	Emissions from the effluent pond	CH_4	P	*Included*
		N_2O		*Excluded*
7	Emissions from land application	N_2O	B, P	*Excluded*
	Vehicle emissions for	CO_2	B, P	*Included*

SSR	GHG Source	Gas	Relevant to Project Baseline (B) or Offset Project (P)	Included/ Excluded
	land application and/or off-site transport	CH_4		*Excluded*
		N_2O		*Excluded*
8	Emissions from combustion during flaring, including emissions from incomplete combustion of biogas	CO_2	P	*Excluded*
		CH_4		*Included*
		N_2O		*Excluded*
9	Emissions from combustion during electric generation, including incomplete combustion of biogas	CO_2	P	*Excluded*
		CH_4		*Included*
		N_2O		*Excluded*
10	Emissions from upgrading biogas for pipeline injection or use as CNG/LNG fuel	CO_2	P	*Included*
		CH_4		*Excluded*
		N_2O		*Excluded*
11	Emissions from combustion at boiler including emissions from incomplete c ombustion of biogas	CO_2	P	*Excluded*
		CH_4		*Included*
		N_2O		*Excluded*
12~~11~~	Emissions from combustion of biogas by end user of pipeline or CNG/LNG, including incomplete combustion	CO_2	P	*Excluded*
		CH_4		*Excluded*
		N_2O		*Excluded*
13~~12~~	Delivery and use of project electricity to grid	CO_2	P	*Excluded*
		CH_4		
		N_2O		
14	Off-site thermal energy or power	CO_2	P	*Excluded*
		CH_4		
		N_2O		
15~~13~~	Use of project-generated thermal energy	CO_2	P	*Excluded*
		CH_4		
		N_2O		
16	Project construction and decommissioning emissions	CO_2	P	*Excluded*
		CH_4		
		N_2O		

5 Quantifying GHG Emission Reductions – Quantification Methodology[~~8~~7]

GHG emission reductions from a livestock offset project are quantified by comparing actual project emissions to baseline emissions at the offset project site. Project ~~B~~baseline emissions are an estimate of the GHG emissions from GHG sources within the ~~GHG Assessment~~Offset Project Boundary that would have occurred in the absence of the livestock offset project. Project emissions are actual GHG emissions that occur at sources within the ~~GHG Assessment~~Offset Project Boundary. Project emissions must be subtracted from the project baseline emissions to quantify the offset project's total net GHG emission reductions (Equation 5.1)~~.~~, and the total number of GHG reductions submitted for issuance of ARB or registry offset credits must be rounded to the nearest whole ton.

The ~~o~~Offset ~~p~~Project ~~o~~Operator~~s~~ or ~~a~~Authorized ~~p~~Project ~~d~~Designee~~s~~ should take note that some equations to calculate project baseline and project emissions are run on a month-by-month basis and activity data monitoring takes place at varying levels of frequency. As applicable, monthly emissions data (for project baseline and offset project) are summed together to calculate annual GHG emission reductions.

The current methodology for quantifying the GHG ~~impact~~emissions and GHG emission reductions associated with installing a BCS requires the use of both modeled reductions (following Equation 5.2 to Equation 5.4 and Equation 5.6 to Equation 5.9), as well as the utilization of ex-post metered data from the BCS to be used as a check on the modeled GHG reductions.

~~ARB recognizes that t~~There can be material differences between modeled methane emission reductions and the actual metered quantity of methane that is captured and destroyed by the BCS due to digester start-up periods, venting events, and other BCS 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, ARB 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 BCS. The lesser of the two values will represent the total methane emission reductions for the reporting period. Equation 5.1 below outlines the quantification methodology for calculating the GHG emission reductions from the installation of a BCS.[~~9~~8]

[~~8~~7] The entirety of Section 5 is considered a quantification method.

[~~9~~8] The calculation procedure only addresses direct emissions sources and does not incorporate ~~changes~~reductions in electricity consumption, which impacts indirect emissions associated with power plants owned and operated by entities other than the Offset Project Operator or Authorized Project Designee~~livestock operator~~. Equation 5.1 accounts for any increase in CO2 if the project results in an increase in electricity consumption.

Equation 5.1. GHG Reductions from Installing a Biogas Control System

$$\textit{Total GHG Reductions} = (\textit{Modeled project baseline emissions}_{CH4} - \textit{Project emissions}_{CH4}) + (\textit{project } \cancel{B}\textit{baseline emissions}_{CO2} - \textit{Project emissions}_{CO2})$$

The (*Modeled project baseline emissions* $_{CH4,}$ – *Project emissions* $_{CH4}$) term shall be calculated according to Equation 5.2 to Equation 5.4 and Equation 5.6 to Equation 5.9. 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 5.10. 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:

$$\textit{Total GHG Reductions} = (\textit{Total quantity of metered and destroyed methane}) + (\textit{Project b}\cancel{B}\textit{aseline emissions}_{CO2} - \textit{Project emissions}_{CO2})$$

5.1 Quantifying Baseline Methane Emissions

Project ~~B~~baseline emissions represent the GHG emissions within the ~~GHG assessment~~Offset Project ~~b~~Boundary that would have occurred if not for the installation of the BCS. For the purposes of this protocol, ~~offset project operators or authorized project designees~~ ~~calculate their~~project baseline emissions must be calculated according to the manure management system in place prior to installing the BCS. This is referred to as a “continuation of current practices” project baseline scenario. Additionally, ~~offset project operators or authorized project designees calculate~~project baseline emissions must be calculated each year of the offset project.[~~10~~9] The procedure assumes there is no BCS in the project baseline system. Regarding new livestock operations that install a BCS, ~~offset project operators or authorized project designees~~ a modeled project baseline scenario must be established ~~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.

The procedure to determine the modeled project baseline methane emissions follows Equation 5.2, which combines Equation 5.3 and Equation 5.4.

Equation 5.3 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.[~~11~~ 10] 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 5.4 is less intensive and applies to non-anaerobic storage/treatment systems. Both Equation 5.3 and Equation 5.4 reflect basic biological principles of methane

~~10~~ 9 Conversely, under a “static baseline,” ~~a project operator would assess~~the project baseline emissions would be assessed once before offset project implementation and ~~use~~ that value would be used throughout the offset project lifetime.

~~11~~ 10 Anaerobic storage/treatment systems generally refer to anaerobic lagoons, or storage ponds, etc.

production from available volatile solids, determine methane generation for each livestock category, and account for the extent to which the waste management system handles each category's manure.

Equation 5.2. Modeled Project Baseline Methane Emissions

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

Where,

			Units
BE_{CH4}	=	Total annual project baseline methane emissions, expressed in carbon dioxide equivalent	tCO_2e/yr
$BE_{CH4,AS,L}$	=	Total annual project baseline methane emissions from anaerobic storage/treatment systems by livestock category 'L', expressed in carbon dioxide equivalent	tCO_2e/yr
$BE_{CH4,non\text{-}AS,L}$	=	Total annual project baseline methane emissions from non-anaerobic storage/treatment systems, expressed in carbon dioxide equivalent	tCO_2e/yr

Equation 5.3. Modeled Project Baseline Methane Emissions from Anaerobic Storage/Treatment Systems

$$BE_{CH4,AS} = \sum_{L,AS} VS_{\deg,AS,L} \times B_{0,L} \times 0.68 \times 0.001 \times 21$$

Where, Units

$BE_{CH4,AS}$	=	Total annual project 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' – see Appendix A, Table A.3	m^3 CH_4/kg of VS
0.68	=	Density of methane (1 atm, 60^oF)	kg/m^3
0.001	=	Conversion factor from kg to metric tons	
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, Units

$VS_{deg,AS,L}$	=	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"	

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

Where, Units

$VS_{avail,AS,L}$	=	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. *Important* – refer to Box 5.1 for using appropriate units for VS_L values from Appendix A	kg/ animal/ day
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' [~~12~~11]	%
dpm	=	Days per month	days/ month
0.8	=	System calibration factor	
$VS_{avail-1,AS}$	=	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

[~~12~~ 11] The MS value represents the percent of manure that would be sent to (managed by) the anaerobic manure storage/treatment systems in the project baseline case – as if the biogas control system was never installed.

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

Where,			Units
f	=	The van't Hoff-Arrhenius factor	
E	=	Activation energy constant (15,175)	cal/mol
T_1	=	303.16	Kelvin
T_2	=	Monthly average ambient temperature (K = °C + 273). If T_2 < 5 °C then *f* = 0.104	Kelvin
R	=	Ideal gas constant (1.987)	cal/Kmol

Equation 5.4. Modeled Project Baseline Methane for Non-Anaerobic Storage/Treatment Systems

$$BE_{CH4,nAS} = \left(\sum_{L,S} P_L \times MS_{L,nAS} \times VS_L \times 365 \times MCF_{nAS} \times B_{0,L}\right) \times 0.68 \times 0.001 \times 21$$

Where,			Units
$BE_{CH4,nAS}$	=	Total annual project 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. *Important* – refer to Box 5.1 for using appropriate units for VS_L values from Appendix A	kg/ animal/ day
365	=	Days in a year	days/yr
$MCF_{,nAS}$	=	Methane conversion factor for non-anaerobic storage/treatment system 'S' – See Appendix A	%
$B_{0,L}$	=	Maximum methane producing capacity for manure for livestock category 'L' – Appendix A, Table A.3	m^3 CH_4/kg of VS dry matter
0.68	=	Density of methane (1 atm, 60°F)	kg/m^3
0.001	=	Conversion factor from kg to metric tons	
21	=	Global Warming Potential factor of methane to carbon dioxide equivalent	

Box 5.1. Daily Volatile Solids for All Livestock Categories

Consistent with international best-practice, it is recommended that appropriate VS_L values for Dairy livestock categories be obtained from the State-specific lookup table~~s (Tables~~ ~~B~~A.5.~~a – B.5.f)~~ provided in Appendix A. ~~When possible, use the year corresponding to the appropriate emission year. If the current year's table is not available, use the most current year.~~

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

Important - Units provided for all VS values in Appendix A are in (kg/day/1000kg), in order to get VS_L in the appropriate units (kg/animal/day), the following equation must be used:

$$VS_L = VS_{table} \times \frac{Mass_L}{1000}$$

Where,			Units
VS_L	=	Volatile solid excretion on a dry matter weight basis	kg/ animal/ day
VS_{Table}	=	Volatile solid excretion from lookup table (Table A.3 and Table A.5a. - A.5.d.)	kg/ day/ 1000kg
$Mass_L$	=	Average live weight for livestock category 'L', if site specific data is unavailable, use values from Appendix A, Table A.2	kg

5.1.1 Variables for Calculating Project Baseline Methane

The calculation procedure uses a combination of site-specific values and default factors.

Population – PL

The procedure requires ~~offset project operators or authorized project designees~~the offset project 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 A, Table A.2). The population of each livestock category is monitored on a monthly basis, and for Equation 5.4 averaged for an annual total population.

Volatile S~~s~~olids – 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). This protocol requires that the VS value for all livestock categories be determined as outlined in Box 5.1.

$Mass_L$

This value is the annual average live weight of the animals, per livestock category. This data is necessary because default VS values are supplied in units of kg/day/1000kg mass, therefore the average mass of the corresponding livestock category is required in order to convert the units of VS into kg/day/animal. 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 A, Table A.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. ~~Offset project operators or authorized project designees use the d~~Default B_0 factors from Appendix A, Table A.3 must be used.

MS

The MS value apportions manure from each livestock category to an 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 cows' 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 5.3 and 15% to Equation 5.4.

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

Methane ~~c~~Conversion ~~f~~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.

~~According to this protocol, f~~For anaerobic lagoons, storage ponds, liquid slurry tanks etc., ~~offset project operators or authorized project designees perform a~~ this protocol requires 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 5.3, which equals the system's monthly available VS~~volatile solids~~ multiplied by "f," the van't Hoff-Arrhenius factor. The 'f' factor effectively converts total available VS~~volatile solids~~ in the anaerobic manure storage/treatment system to methane-convertible VS~~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.

Default MCF values for non-anaerobic manure storage/treatment are available in Appendix A, which are used for Equation 5.4.

5.2 Quantifying Project Methane Emissions

Project emissions are actual GHG emissions that occur within the ~~GHG Assessment~~ Offset Project Boundary after the installation of the BCS. Project emissions are calculated on an annual, *ex-post* basis. But like project 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.

As shown in Equation 5.5, project methane emissions equal:

- The amount of methane created by the BCS that is 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 BCS 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 project baseline methane calculation approach, the formula to account for project methane emissions incorporates all potential GHG sources within the waste treatment and storage category. Non-BCS-related sources follow the same calculation approach as provided in the project baseline methane equations. Several activity data for the variables in Equation 5.9 will be the same as those in Equation 5.2 – Equation 5.4.

Although not common under normal digester operation, it is possible that a venting event may occur due to failure of digester cover materials, the digester vessel, or the gas collection system, or due to a planned maintenance event. In the event that a system failure or planned operation results in the venting of biogas, the quantity of methane released to the atmosphere shall be estimated according to Equation 5.7.

Equation 5.5. Project Methane Emissions

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

Where,

			Units
PE_{CH4}	=	Total annual project methane emissions, expressed in carbon dioxide equivalent	tCO_2e/yr
$PE_{CH4,\ BCS}$	=	Annual methane emissions from the BCS – Equation 5.6	tCH_4/yr
$PE_{CH4,\ EP}$	=	Annual methane emissions from the BCS Effluent Pond – Equation 5.8	tCH_4/yr
$PE_{CH4,\ non\text{-}BCS}$	=	Annual methane emissions from sources in the waste treatment and storage category other than the BCS and associated Effluent Pond – Equation 5.9	tCH_4/yr
21	=	Global Warming Potential factor of methane to carbon dioxide equivalent	

Equation 5.6. Project Methane Emissions from the Biogas Control System

$$PE_{CH4,BCS} = \left[\left(\mathrm{CH}_{4,\mathrm{meter}}\right)\left(\left(\frac{1}{BCE}\right) - BDE_{i,weighted} \right) \right] + CH_{4,vent,i}$$

Where, — Units

$PE_{CH4,\ BCS}$	=	Monthly methane emissions from the BCS, to be aggregated annually	tCH_4/yr
$CH_{4,meter}$	=	Monthly quantity of methane collected and metered	tCH_4/ month
BCE	=	Monthly methane collection efficiency of the BCS. Offset Project Operators or Authorized Project Designees~~offset project operators or authorized project designees~~ use the appropriate default value provided in Table A.4	% (as a decimal)
$BDE_{i,weighted}$	=	Monthly weighted average of all destruction devices used in month i.	% (as a decimal)
$CH_{4,vent,i}$	=	The monthly quantity of methane that is vented to the atmosphere due to BCS venting events, as quantified in Equation 5.7 below.	

$$CH_{4,meter} = F \times (520/T)^{\pi} \times (P/1)^{\pi} \times CH_{4,conc} \times 0.0423 \times 0.000454$$

Where, — Units

$CH_{4,meter}$	=	Monthly quantity of methane collected and metered[~~13~~12]	tCH_4/ month
F	=	Measured volumetric flow of Biogas per month	scf/month

[~~13~~ 12] This value reflects directly measured biogas mass flow and methane concentration in the biogas to the combustion device.

Equation 5.6. Continued

T	=	Temperature of the Biogas flow ($^oR = ^oF + 459.67$)	^{o}R (Rankine)
P	=	Pressure of the Biogas flow	atm
$CH_{4,conc}$	=	Measured methane concentration of Biogas from the most recent methane concentration measurement	% (as a decimal)
0.0423	=	Density of methane gas (1atm, 60^oF)	$lbsCH_4/scf$
0.000454	=	Conversion factor, lbs to metric tons	

** The terms (520/T) and (P/1) should be omitted if the continuous flow meter internally corrects for temperature and pressure to 60^oF and 1atm.*

$$BDE_{i,weighted} = \frac{\sum_{DD}\left(BDE_{DD} \times F_{i,DD}\right)}{F_i}$$

Where, Units

$BDE_{i,weighted}$	=	Monthly weighted average of all destruction devices used in month i	fraction
BDE_{DD}	=	Default methane destruction efficiency of a particular destruction device 'DD'. See Appendix A for default destruction efficiencies by destruction device[~~14~~13]	fraction
$F_{i,DD}$	=	Monthly flow of biogas to a particular destruction device 'DD'	scf/month
F_i	=	Total monthly measured volumetric flow of biogas to all destruction devices	scf/month

Equation 5.7. Project Methane Emissions from Venting Events

$$CH_{4,vent,i} = \left(MS_{BCS} + (F_{pw} \times t)\right) \times CH_{4,conc} \times 0.04230 \times 0.000454$$

Where, Units

MS_{BCS}	=	Maximum biogas storage of the BCS system	SCF
F_{pw}	=	The average total flow of biogas from the digester for the entire week prior to the venting event	SCF/day
t	=	The average total flow of biogas from the digester for the entire week prior to the venting event	days

[~~14~~ 13] Offset Project ~~o~~Operators or Authorized Project Designees have the option to use either the default methane destruction efficiencies provided, or site specific methane destruction efficiencies as provided by an ARB approved source test plan, for each of the combustion devices used in the project.

Equation 5.8. Project Methane Emissions from the BCS Effluent Pond[~~15~~] [14]

$$PE_{CH4,EP} = VS_{ep} \times B_{o,ep} \times 365 \times 0.68 \times MCF_{ep} \times 0.001$$

Where,			Units
$PE_{CH4,\,EP}$	=	Methane emissions from the Effluent Pond	tCH_4/yr
VS_{ep}	=	Volatile solid to effluent pond – 30% of the average daily VS entering the digester	kg/day
$B_{o,ep}$	=	Maximum methane producing capacity (of VS dry matter)[~~16~~15]	m^3CH_4/kg
365	=	Days in a year	days/yr
0.68	=	Density of methane (1 atm, 60^oF)	kg/m^3
MCF_{ep}	=	Methane conversion factor, Appendix A. ~~o~~Offset ~~p~~Project ~~o~~Operators ~~or~~ or ~~a~~Authorized ~~p~~Project ~~d~~Designees shall use the *liquid slurry* MCF value for effluent ponds	Fraction
0.001	=	Conversion factor from kg to metric tons	

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

Where,			Units
VS_L	=	VS~~olatile solids~~ produced by livestock category 'L' on a dry matter basis. *Important* – refer to Box 5.1 for using appropriate units for VS_L values from Appendix A	kg/ animal/ day
P_L	=	Annual average population of livestock category 'L' (based on monthly population data	
$MS_{L,BCS}$	=	Fraction of manure from livestock category 'L' that is managed in the BCS	fraction
0.3	=	Default value representing the amount of VS that exits the digester as a percentage of the VS entering the digester	fraction

[~~15~~] [14] If no effluent pond exists and Offset ~~p~~Project ~~o~~Operators or Authorized Project Designees 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 5.8

[~~16~~] [15] The B_o value for the project effluent pond is not differentiated by livestock category. Offset Project ~~o~~Operators or Authorized Project Designees 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 5.9. Project Methane Emissions from *Non*-BCS Related Sources[~~17~~16]

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

Where, Units

$PE_{CH4,\,nBCS}$	=	Methane from sources in the waste treatment and storage category other than the BCS and associated Effluent Pond	tCH_4/yr
$EF_{CH4,L}$	=	Emission factor for the livestock population from non-BCS-related sources (nBCSs, calculated below)	$kgCH_4$/ head/ yr
P_L	=	Population of livestock category 'L'	
0.001	=	Conversion factor from kg to metric tons	

$$EF_{CH4,L}(nBCSs) = (VS_L \times B_{o,L} \times 365 \times 0.68) \times \left(\sum_{S} (MCF_S \times MS_{L,S}) \right)$$

Where, Units

$EF_{CH4,L}$	=	Methane emission factor for the livestock population from non-biogas control system related sources (nBCSs)	$kgCH_4$/ head/ yr
VS_L	=	Volatile solids produced by livestock category 'L' on a dry matter basis. *Important* – refer to Box 5.1 for using appropriate units for VS_L values from Appendix A	kg/ animal/ day
$B_{o,L}$	=	Maximum methane producing capacity for manure for livestock category 'L' (of VS dry matter), Appendix A, Table A.3	m^3 CH_4/kg
365	=	Days in a year	days/yr
0.68	=	Density of methane (1 atm, 60^oF)	kg/m^3
MCF_S	=	Methane conversion factor for system component 'S', Appendix A	fraction
$MS_{L,S}$	=	Percent of manure from livestock category L that is managed in non-BCS system component 'S'	fraction

5.3 Metered Methane Destruction Comparison

As described above, ~~ARB requires~~ all offset projects must~~to~~ compare the modeled methane emission reductions for the reporting period, as calculated in Equation 5.2 - Equation 5.4 and Equation 5.6 - Equation 5.9 above, with the actual metered amount of methane that is destroyed in the BCS 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 BCS must be aggregated over the reporting period. In the event that an ~~the o~~Offset ~~p~~Project ~~o~~Operator or ~~a~~Authorized ~~p~~Project ~~d~~Designee is reporting GHG reductions for a period of time that is 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 BCS over the same period of time. For example, if a project is reporting and verifying only 6 months of data, July – December for instance, the modeled emission reductions over this 6

[~~17~~ 16] 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).

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 5.10 below details the metered methane destruction calculation.

Equation 5.10. Metered Methane Destruction

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

Where,			Units
$CH_{4,destroyed}$	=	Aggregated quantity of methane collected and destroyed during the reporting period	tCO_2e/yr
$CH_{4,meter}$	=	Monthly quantity of methane collected and metered. See Equation 5.6	tCH_4/ month
$BDE_{i,weighted}$	=	Monthly weighted average of all destruction devices used in month i~~[18]~~ [17] See Equation 5.6	% (as a decimal)
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 Equation 5.2 - Equation 5.4 and Equation 5.6 - Equation 5.9 for the reporting period, the methane emission reductions are equal to $CH_{4,destroyed}$
- Otherwise, the methane emission reductions are equal to ($BE_{CH4} – PE_{CH4}$)

5.4 Quantifying Project Baseline and Project Carbon Dioxide Emissions

~~Sources of c~~Carbon dioxide emissions associated with the project baseline or ~~a~~ project activities~~may~~ include sources like electricity use by pumps and equipment, fossil fuel generators used to destroy biogas or power pumping systems or milking parlor equipment, flares, tractors that operate in barns or freestalls, on-site manure hauling trucks, or vehicles that transport manure off-site. ~~Changes in carbon dioxide emissions from these sources may be small, but a~~ Any net increase in emissions shall be accounted for. ~~Offset project operators or authorized project designees may either u~~Use Equation 5.11 to calculate the net change in carbon dioxide emissions, or, if it~~they~~ can be demonstrated during verification that project carbon dioxide emissions are estimated to be equal to or less than 5% of the total project baseline emissions of methane, ~~the offset project operator or authorized project designee may estimate~~ project baseline and project carbon dioxide emissions may be estimated. All estimates or calculations of anthropogenic carbon dioxide emissions within the ~~GHG Assessment~~ Offset Project Boundary must be verified and included in GHG emission reduction calculations.

~~[18]~~ [17] The Offset Project ~~o~~Operator~~s~~ or Authorized Project Designee ~~have~~has the option to use either the default methane destruction efficiencies provided, or site specific methane destruction efficiencies as provided by an ARB approved source test plan, for each of the combustion devices used in the project.

If calculations or estimates indicate that the offset project results in a net decrease in carbon dioxide emissions from grid-delivered electricity, mobile and stationary sources, then for quantification purposes the net change in these emissions must be specified as zero (i.e., $CO_{2,net} = 0$ in Equation 5.11).

Carbon dioxide emissions from the combustion of biogas are considered biogenic emissions and are excluded from the GHG Assessment Boundary.

Equation 5.11 below calculates the net change in anthropogenic carbon dioxide emissions resulting from the offset project activity.

Equation 5.11. Carbon Dioxide Emission Calculations

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

Where,

			Units
$CO_{2,net}$	=	Net change in anthropogenic carbon dioxide emissions from electricity consumption and mobile and stationary combustion sources resulting from project activity	tCO_2/yr
BE_{CO2MSC}	=	Total annual baseline carbon dioxide emissions from electricity consumption and mobile and stationary combustion sources (see equation below)	tCO_2/yr
PE_{CO2MSC}	=	Total annual project carbon dioxide emissions from electricity consumption and mobile and stationary combustion sources (see equation below)	tCO_2/yr

All electricity consumption and stationary and mobile combustion are calculated using the equation:

$$CO_{2,MSC} = \left(\sum_c QE_c \times EF_{CO2,e}\right) + \left[\left(\sum_c QF_c \times EF_{CO2,f}\right) \times 0.001\right]$$

Where,

			Units
$CO_{2,MSC}$	=	Anthropogenic carbon dioxide emissions from electricity consumption and mobile and stationary combustion sources	tCO_2
QE_c*	=	Quantity of electricity consumed for each emissions source 'c'	MWh/yr
$EF_{CO2,e}$	=	CO_2 emission factor *e* for electricity used; see Appendix A for emission factors by eGRID subregion	tCO_2/MWh
$EF_{CO2,f}$	=	Fuel-specific emission factor *f* from Appendix A	kg CO_2/ MMBTU or kg CO_2/ gallon
QF_c	=	Quantity of fuel consumed for each mobile and stationary emission source 'c'	MMBTU/yr or gallon/yr
0.001	=	Conversion factor from kg to metric tons	

* If total electricity being generated by project activities is > the additional electricity consumption, then QE_c shall not be accounted for in the project emissions and shall be omitted from the equation above.

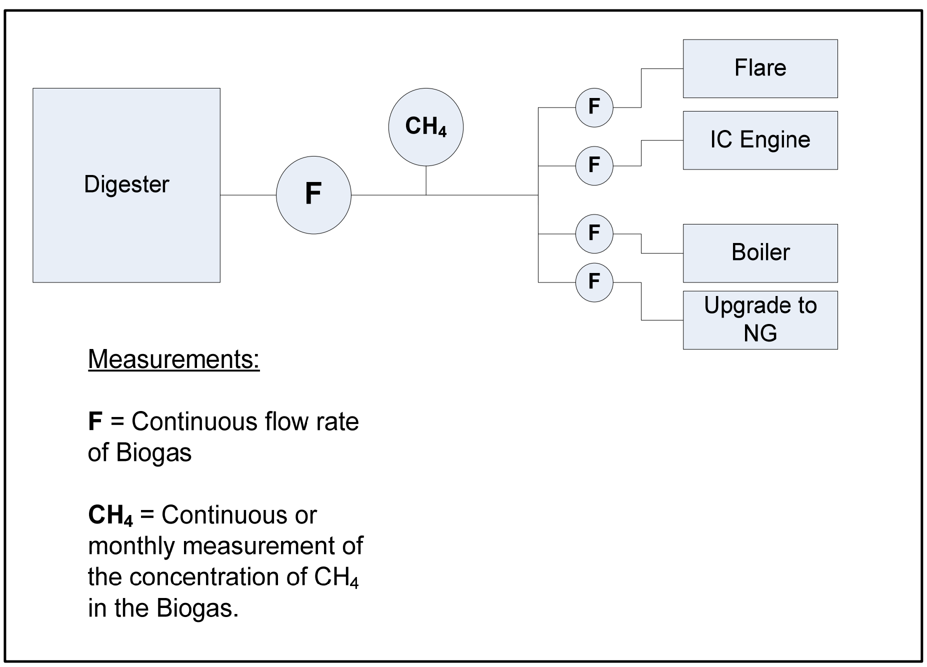
6 Offset Project Documentation and Monitoring Requirements

The ~~o~~Offset ~~p~~Project ~~o~~Operator~~s~~ or ~~a~~Authorized ~~p~~Project ~~d~~Designee~~s are~~ is responsible for monitoring the performance of the offset project and operating each component of the biogas collection and destruction system in a manner consistent with the manufacturer's specifications. The methane capture and control system must be monitored with measurement equipment that directly meters:

1. The total flow of biogas, measured continuously and recorded every 15 minutes or totalized and recorded at least daily, adjusted for temperature and pressure, prior to delivery to the destruction device(s)
2. The flow of biogas delivered to each destruction device~~[19]~~[18], measured continuously and recorded every 15 minutes or totalized and recorded at least daily, adjusted for temperature and pressure
3. The fraction of methane in the biogas, measured with a continuous analyzer or, alternatively, with quarterly measurements

Flow data must be corrected for temperature and pressure at 60^{o}F and 1 atm, either internally or by following Equation 5.6.

Figure 6.1 represents the suggested arrangement of the biogas flow meters and methane concentration 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 example includes one more flow meter than would be necessary to achieve this objective.

~~[19]~~[18] A ~~single~~ meter ~~may~~must be used ~~for multiple, identical~~for each destruction device~~s. In this instance, methane destruction in these units will be eligible only if both units are monitored to be operational~~, even if the destruction device is identical.

Operational activity of the destruction devices shall be monitored and documented at least hourly to ensure actual methane destruction. GHG reductions will not be accounted for or credited during periods in which the destruction device is not operational.

If for any reason the destruction device or the operational monitoring equipment (for example, the thermal coupler on the flare) is inoperable, all metered biogas going to the particular device shall be assumed to be released to atmosphere during the period of inoperability. During the period of inoperability, the destruction efficiency of the device must be assumed to be zero. In Equation 5.10, the monthly biogas destruction efficiency (BDE) value shall be adjusted accordingly. See Box 6.1 for an example BDE adjustment.

Box 6.1. Example BDE Adjustment

As an example, consider a situation where the primary destruction device is 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. Assume that the total flow of biogas to the flare for the month is 3,000,000 scf, and that the total flow recorded for the 5 day period of inoperability is 500,000 SCF. In this case the monthly BDE would be adjusted as follows:

*BDE =[(0.96*2,500,000) +(0.0 * 500,000)] / 3,000,000 = 80%*

6.1 ~~6.1.1~~ Biogas Measurement Instrument QA/QC – Quantification Methodology

All gas flow meters[20] and continuous methane analyzers must be:

- Cleaned and inspected on a quarterly basis, with the activities performed and "as found/as left condition" of the equipment documented

- Field checked by a trained professional for calibration accuracy with the percent drift documented, using either a portable instrument (such as a pitot tube)[21] or manufacturer specifications, at the end of but no more than two months prior to the end date of the reporting period[22]

- Calibrated by the manufacturer or a certified calibration service per manufacturer's specifications or every 5 years, whichever is more frequent

If the field check on a piece of equipment reveals accuracy outside of a +/- 5% threshold, calibration by the manufacturer or a certified service provider is required for that piece of equipment.

~~20~~ 19 Field checks and calibrations of flow meters shall assess the volumetric output of the flow meter.

~~21~~ 20 It is recommended that a professional third party calibration service be hired to perform flow meter field checks if using pitot tubes or other portable instruments, as these types of devices require professional training in order to achieve accurate readings.

~~22~~ 21 Instead of performing field checks, the Offset ~~p~~Project ~~o~~Operators or Authorized Project Designees may instead have equipment calibrated by the manufacturer or a certified calibration service per manufacturer's specifications, at the end of but no more than two months prior to the end date of the reporting period to meet this requirement.

For the interval between the last successful field check and any calibration event confirming accuracy below the +/- 5% threshold, all data from that meter or analyzer must be scaled according to the following procedure. These adjustments must be made for the entire period from the last successful field check until such time as the meter is properly calibrated.

1. For calibrations that indicate under-reporting (lower flow rates, or lower methane concentration), the metered values must be used without correction.
2. For calibrations that indicate over-reporting (higher flow rates, or higher methane concentration), the metered values must be adjusted based on the greatest calibration drift recorded at the time of calibration.

For example, if a project conducts field checks quarterly during a year-long reporting period, only three months of data will be subject at any one time to the penalties above. However, if the ~~o~~Offset ~~p~~Project ~~o~~Operator or ~~a~~Authorized ~~p~~Project ~~d~~Designee feels confident that the meter does not require field checks or calibration on a greater than annual basis, then failed events will accordingly require the penalty to be applied to the entire year's data. Frequent calibration may minimize the total accrued drift (by zeroing out any error identified), and result in smaller overall deductions.

In order to provide flexibility in verification, data monitored up to two months after a field check may be verified. As such, the end date of the reporting period must be no more than two months after the latest successful field check.

If a portable instrument is used (such as a handheld methane analyzer), the portable instrument shall be calibrated at least annually by the manufacturer or at an ISO 17025 accredited laboratory.

6.1.1 ~~6.1.2~~ Missing Data – Quantification Methodology

In situations where the flow rate or methane concentration monitoring equipment is missing data, the ~~o~~Offset ~~p~~Project ~~o~~Operator or ~~a~~Authorized ~~p~~Project ~~d~~Designee shall apply the data substitution methodology provided in Appendix B. If for any reason the destruction device monitoring equipment is inoperable (for example, the thermal coupler on the flare), no emission reductions can be credited for the period of inoperability.

6.2 Monitoring Parameters – Quantification Methodology

Provisions for monitoring other variables to calculate project baseline and project emissions are provided in Table 6.1. The parameters are organized by general project factors and then by the calculation methods.

Table 6.1. Project Monitoring Parameters

Parameter	Description	Data unit	calculated (c) measured (m) reference(r) operating records (o)	Measurement frequency	Comment
General Project Parameters					
Regulations	Offset Project ~~o~~Operator and Authorized Project Designee compliance with regulatory requirements relating to the manure digester offset project	Environmental regulations	n/a	Annually	Information used to: 1) To demonstrate ability to meet the Legal Requirement Test – where regulation would require the installation of a BCS. 2) To demonstrate compliance with associated regulatory requirements and environmental ~~rules~~ assessments as required by the Regulation, e.g. criteria pollutant and effluent discharge limits. *Verifier:* Determine regulatory agencies responsible for regulating livestock operation; Review regulations, environmental assessments 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 A, Table A.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 A, Table A.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; Review local air and water quality agency reporting submissions, if available (e.g. in CA, dairies with more than 500 cows report farm information to ARB).
$Mass_L$	Average live weight by livestock category	kg	o, r	Monthly	From operating records, or if on-site data is unavailable, from lookup table (Appendix A Table A.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 A, Table A.3. *Verifier*: Verify correct value from table used.
MCF_S	Methane conversion factor for manure management system component 'S'	Percent (%)	r	Annually	From Appendix A. Differentiate by livestock category *Verifier*: Verify correct value from table used.
VS_L	Daily volatile solid production	(kg/animal/day)	r, c	Annually	Appendix A, Table A.3 and Table A.5a-d; see Box 5.1 to convert units from (kg/day/1000kg) to (kg/animal/day). *Verifier*: Ensure appropriate year's table is used; Review data units.

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. *Verifier*: Ensure proper calculations; Review operating records.
VS_{deg}	Monthly volatile solids degraded in each anaerobic storage system, for each livestock category	~~K~~kg	c, o	Monthly	Calculated value from operating records. *Verifier*: Ensure proper calculations; 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. *Verifier*: Ensure proper calculations; Review calculation; Review temperature data.
Project Methane Calculation Variables – BCS + Effluent Pond					
$CH_{4,\ destroyed}$	Aggregated amount of methane collected and destroyed in the BCS	Metric tons of CH_4	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 BCS	Metric tons of CH_4 (tCH_4)	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 and maintenance in accordance with the manufacturer's specifications; Confirm meter calibration data.
F	Monthly volume of biogas from digester to destruction devices	scf/month	m	Continuously, aggregated monthly	Measured continuously from flow meter and recorded every 15 minutes or totalized and recorded at least once 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; Confirm meter calibration data.
T	Temperature of the biogas	°R (Rankine)	m	Continuously, averaged monthly	Measured to normalize volume flow of biogas to STP. No separate monitoring of temperature is necessary when using flow meters that automatically measure temperature and pressure, expressing biogas volumes in normalized cubic feet.
P	Pressure of the biogas	atm	m	Continuously, averaged monthly	Measured to normalize volume flow of biogas to STP. No separate monitoring of pressure is necessary when using flow meters that automatically measure temperature and pressure, expressing biogas volumes in normalized cubic feet.

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 Equation 5.6. *Verifier*: Confirm evidence of 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	Use default value from Table A.4 *Verifier:* Review operation and maintenance records to ensure proper functionality of BCS.
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.
$MS_{L,BCS}$	Fraction of manure from each livestock category managed in the BCS	Percent (%)	o	Annually	Used to determine the total VS entering the digester. The percentage should be tracked in operational records. *Verifier*: Check operational records and conduct site visit.

Parameter	Description	Data unit	calculated (c) measured (m) reference(r) operating records (o)	Measurement frequency	Comment
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 BCS. *Verifier:* Check calculation.
MCF_{ep}	Methane conversion factor for BCS effluent pond	Percent (%)	r	Annually	Referenced from Appendix A. <u>The</u> ~~o~~<u>O</u>ffset ~~p~~Project ~~o~~<u>O</u>perators or ~~a~~<u>A</u>uthorized ~~p~~<u>P</u>roject ~~d~~<u>D</u>esignee~~s~~ should use the *liquid slurry* MCF value. *Verifier*: Verify value from table.
MS_{BCS}	The maximum biogas storage of the BCS system	scf	r	Annually	Obtained from digester system design plans. Necessary to quantify the release of methane to the atmosphere due to an uncontrolled venting event.
F_{pw}	The average flow of biogas from the digester for the entire week prior to the uncontrolled venting event	scf/day	m	Weekly	The average flow of biogas can be determined from the daily records from the previous week.
t	The number of days of the month that biogas is venting uncontrolled from the project's BCS.	Days	m, o	Monthly	The number of days of the month that biogas is venting uncontrolled from the project's BCS.

Parameter	Description	Data unit	calculated (c) measured (m) reference(r) operating records (o)	Measurement frequency	Comment
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 5.9. *Verifiers*: Review calculation, operation records.
Baseline and Project CO_2 Calculation Variables					
$EF_{CO2,f}$	Fuel-specific emission factor for mobile and stationary combustion sources	kg CO_2/MMBTU or kg CO_2/gallon	r	Annually	Refer to Appendix A for emission factors. If biogas produced from digester is used as an energy source, the emission factor~~EF~~ is zero. *Verifier*: Review emission factors.
QF_c	Quantity of fuel used for mobile/stationary combustion sources	MMBTU/year or gallon/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. *Verifier:* Review operating records and quantity calculation.
$EF_{CO2,e}$	Emission factor for electricity used by project	tCO2/MWh	r	Annually	Refer to Appendix A for emission factors. If biogas produced from digester is used to generate electricity consumed, the emission factor~~EF~~ is zero. *Verifier*: Review emission factors.
QE_c	Quantity of electricity consumed	MWh/year	o, c	Annually	Electricity used by project for manure collection, transport, treatment/storage, and disposal. *Verifier:* Review operating records and quantity calculation.

7 Reporting Parameters

General requirements for reprinting and record retention are included in the Regulation. This section includes additional requirements specific to this protocol.~~This section provides requirements on reporting and procedures.~~ ~~It is a~~A priority of this protocol is to facilitate consistent and transparent information disclosure ~~among project operators~~ by Offset Project Operators or Authorized Project Designees.

7.1 Annual Reporting Requirements

The Offset ~~p~~Project ~~o~~Operator~~s~~ or ~~a~~Authorized ~~p~~Project ~~d~~Designee~~s~~ must submit an Offset Project Data ~~r~~Report ~~information contained in Appendix D~~according to the requirements in the Regulation. The Offset Project Data Report must include the information listed in the Regulation and this protocol and cover a single Reporting Period. See the Regulation and Appendix D for specific requirements.

7.2 Document Retention

The Offset ~~p~~Project ~~o~~Operator~~s~~ or ~~a~~Authorized ~~p~~Project ~~d~~Designee~~s~~ ~~are~~is required to keep all documentation and information outlined in ~~this protocol as required in~~ the Regulation and this protocol. Record~~s~~ retention requirements are set forth in the Regulation. ~~must be retained for a period of 5 years after the end of the crediting period~~.

System Information that should be retained by the Offset ~~p~~Project ~~o~~Operator or ~~a~~Authorized ~~p~~Project ~~d~~Designee should include, but is not limited to:

- All data inputs for the calculation of the project baseline emissions and project emission reductions
- CO_2e annual tonnage calculations
- Relevant sections of the BCS operating permits
- BCS information (installation dates, equipment list, etc.)
- Biogas flow meter information (model number, serial number, manufacturer's calibration procedures)
- Cleaning and inspection records for all biogas meters
- Field check results for all biogas meters
- Calibration results for all biogas meters
- Methane monitor information (model number, serial number, calibration procedures)
- Biogas flow 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
- Destruction device monitoring data (for each destruction device)
- Destruction device, methane monitor and biogas flow monitor information (model numbers, serial numbers, calibration procedures)
- All maintenance records relevant to the BCS, monitoring equipment, and destruction devices

If using a calibrated portable gas analyzer for CH_4 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

See the Regulation for record-keeping requirements.

7.3 ~~Reporting Period &~~ Verification Cycle

Offset project verification schedules are set forth in the Regulation.
~~Offset project operators or authorized project designees must submit an Offset Project Data Report to ARB or an Offset Project Registry annually and be based on a single calendar year.~~

~~Verification must be performed annually and be based on a calendar year. A verification statement must be received by ARB by October 1 of the next calendar year for which the statement is verifying destruction.~~

8 Glossary of Terms[23]

~~Accredited verifier~~	~~A verification firm approved by ARB to provide verification services for offset project operators or authorized project designees.~~
~~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	Gas that is produced from the breakdown of organic material in the absence of oxygen. Biogas is produced in processes including, but not limited to, anaerobic digestion, anaerobic decomposition, and thermochemical decomposition. These processes are applied to biodegradable biomass materials, such as manure, sewage, municipal solid waste, green waste, and waste from energy crops, to produce landfill gas, digester gas, and other forms of 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.~~
~~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.~~
~~Direct emissions~~	~~Greenhouse gas emissions from sources that are owned or controlled by the reporting entity.~~

[23] For terms not defined in this section, the definitions in the Regulation apply.

Emission factor	A unique value for determining an amount of a greenhouse gas emitted for a given quantity of activity data (e.g. metric tons 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)~~	~~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 ton (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 (CH_4)	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.~~

~~Offset project operators or authorized project designees~~	~~An entity that undertakes a project activity, as identified in the Livestock Project Protocol. A project operator 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.
~~Verification~~	~~The process used to ensure that a given participant's greenhouse gas emissions or emission reductions have met the minimum quality standard and complied with ARB's procedures and protocols for calculating and reporting GHG emissions and emission reductions.~~
~~Verification body~~	~~An accredited firm that is able to render a verification opinion and provide verification services for operators subject to reporting under this protocol.~~

9 References

~~ARB exclusively used the CAR Livestock Project Protocol Versions 2.2 and 3.0 as the sole references for this document, and as such, all sources can be found in the CAR documents.~~

Climate ActionReserve~~CAR~~ (2009) Livestock Project Protocol Version 2.2. November 3, 2009
http://www.climateactionreserve.org/wp-content/uploads/2009/03/Livestock-Project-Protocol-Version2.2.pdf (accessed November 3, 2009)

Climate ActionReserve~~CAR~~ (2010) ~~Draft~~ Livestock Project Protocol Version 3.0. September 29, 2010
http://www.climateactionreserve.org/wpcontent/uploads/2009/03/U.S._Livestock_Project_Protocol_V3.02.pdf (accessed September 29, 2010)
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EPA Climate Leaders, Stationary Combustion Guidance (2008).
http://www.epa.gov/climateleaders/documents/resources/stationarycombustionguidance.pdf (accessed May 2008)

EPA eGRID2007, Version 1.1 Year 2005 GHG Annual Output Emission Rates (2008).
http://www.epa.gov/cleanenergy/documents/egridzips/eGRID2007V1_1_year05_GHGOutputRates.pdf (accessed December, 2008)

Appendix A Emission Factor Tables – Quantification Methodology

Table A.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.

Table A.2. Livestock Categories and Typical Average Mass (TAM)

Livestock Category (L)	Livestock Typical Average Mass (TAM) in kg
Dairy cows (on feed)	604~~[b]~~
Non-milking dairy cows (on feed)	684~~[a]~~
Heifers (on feed)	476~~[b]~~
Bulls (grazing)	750~~[b]~~
Calves (grazing)	118~~[b]~~
Heifers (grazing)	420~~[b]~~
Cows (grazing)	533~~[b]~~
Nursery swine	12.5~~[a]~~
Grow/finish swine	70~~[a]~~
Breeding swine	198~~[b]~~

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

Livestock category (L)	VS_L (kg/day/1,000 kg mass)	$B_{o,L}$ ~~[b]~~ (m^3 CH_4/kg VS added)
Dairy cows	See Appendix A, Table~~s~~ A.5.~~a-e~~	0.24
Non-milking dairy cows	5.56	0.24
Heifers	See Appendix A, Table~~s~~ A.5.~~a-e~~	0.17
Bulls (grazing)	6.04~~[b]~~	0.17
Calves (grazing)	6.41~~[b]~~	0.17
Heifers (grazing)	See Appendix A, Table~~s~~ A.5.~~a-e~~	0.17
Cows (grazing)	See Appendix A, Table~~s~~ A.5.~~a-e~~	0.17
Nursery swine	8.89~~[b]~~	0.48
Grow/finish swine	5.36~~[b]~~	0.48
Breeding swine	2.71~~[b]~~	0.35

Table A.4. Biogas Collection Efficiency (BCE) by Digester Type

Digester Type	Cover Type	Biogas Collection Efficiency (BCE) as a decimal
Covered Anaerobic Lagoon	Bank-to-Bank, impermeable	0.95 (95%)
Complete mix, plug flow, or fixed film digester	Enclosed vessel	0.98 (98%)

Table A.5. 2007 Volatile Solid (VS) Default Values for Dairy Cows, Heifers, Heifers-Grazing and Cows-Grazing by State (kg/day/1000 kg mass)

State	VS Dairy Cow	VS Heifer	VS Heifer –Grazing	VS Cows-Grazing
Alabama	8.02	7.42	7.82	7.02
Alaska	8.18	7.42	10.08	9.02
Arizona	10.55	7.42	10.41	9.02
Arkansas	7.11	8.22	7.87	7.00
California	8.98	7.42	7.92	6.85
Colorado	9.11	7.42	7.65	6.46
Connecticut	8.22	6.70	7.66	6.90
Delaware	7.60	6.70	7.89	6.90
Florida	8.40	7.42	7.77	7.02
Georgia	8.80	7.42	7.89	7.02
Hawaii	7.52	7.42	10.30	9.02
Idaho	10.34	7.42	10.80	9.02
Illinois	8.08	7.42	*8.11*	6.91
Indiana	*8.49*	7.42	*8.01*	6.91
Iowa	*8.43*	7.42	*8.20*	6.91
Kansas	*8.35*	7.42	*7.68*	6.46
Kentucky	7.70	7.42	7.97	7.02
Louisiana	6.88	8.22	7.75	7.00
Maine	7.88	6.70	7.66	6.90
Maryland	7.94	6.70	7.85	6.90
Massachusetts	7.69	6.70	7.78	6.90
Michigan	9.05	7.42	7.95	6.91
Minnesota	8.13	7.42	8.05	6.91
Mississippi	8.09	7.42	7.85	7.02
Missouri	7.21	7.42	7.88	6.91
Montana	8.05	7.42	7.21	6.46
Nebraska	*7.98*	7.42	*7.64*	6.46
Nevada	*9.75*	7.42	10.5	9.02
New Hampshire	8.58	*6.70*	7.78	6.90
New Jersey	7.64	6.70	7.92	6.90
New Mexico	10.03	7.42	10.64	9.02
New York	8.24	6.70	7.99	6.90
North Carolina	9.07	7.42	*7.85*	7.02
North Dakota	*7.29*	7.42	*7.40*	6.46
Ohio	*7.94*	7.42	*7.94*	6.91
Oklahoma	*8.04*	8.22	*8.09*	7.00
Oregon	9.49	7.42	10.61	9.02
Pennsylvania	8.27	6.70	8.03	6.90
Rhode Island	7.56	6.70	7.66	6.90
South Carolina	8.73	7.42	7.85	7.02
South Dakota	8.24	7.42	7.50	6.46
Tennessee	8.21	7.42	7.92	7.02
Texas	9.19	8.22	8.20	7.00
Utah	9.75	7.42	10.58	9.02
Vermont	*7.95*	6.70	7.92	6.90
Virginia	8.64	7.42	7.95	7.02
Washington	10.54	7.42	10.87	9.02
West Virginia	7.29	6.70	7.82	6.90
Wisconsin	8.25	7.42	7.88	6.91
Wyoming	8.13	7.42	7.34	6.46

Table A.6.a IPCC 2006 Methane Conversion Factors by Manure Management System Component/Methane Source 'S'

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%			Judgment 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%			Judgment 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 judgment of IPCC Expert Group and Amon et al. (1998).
Dry lot		1.0%					1.5%											2.0%			Judgment 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 %	Judgment 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.
	W/out natural crust cover	17 %	19 %	20 %	22 %	25 %	27 %	29 %	32 %	35 %	39 %	42 %	46 %	50 %	55 %	60 %	65 %	71 %	78 %	80 %	Judgment 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.

Table A.6.a Continued

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%	Judgment 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%			Judgment of IPCC Expert Group in combination with Moller et al. (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%	Judgment of IPCC Expert Group in combination with Mangino et al. (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.

Table A.6.a Continued

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%			Judgment of IPCC Expert Group in combination with Safley et al. (1992).
Cattle and Swine deep bedding	< 1 month	3%					3%											30%			Judgment 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%	Judgment of IPCC Expert Group in combination with Mangino et al. (2001).
Composting - In-vessel[b]		0.5%					0.5%											0.5%			Judgment 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%			Judgment of IPCC Expert Group and Amon et al. (1998). MCFs are less than half of solid storage. Not temperature dependant.

Table A.6.a Continued

Composting - Intensive windrow[b]	0.5%	1.0%	1.5%	Judgment 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%	Judgment 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 A.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 A.6.b. Biogas Destruction Efficiency Default Values by Destruction Device

If available, the actual source test results for the measured methane destruction efficiency shall be used in place of the default methane destruction efficiency. Otherwise, the Offset ~~p~~Project ~~o~~Operator~~s~~ or ~~a~~Authorized ~~p~~Project ~~d~~Designee~~s~~ has~~ve~~ 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 performed on an annual basis.

Biogas Destruction Device	Biogas Destruction Efficiency (BDE)*
Open Flare	0.96~~[1]~~
Enclosed Flare	0.995~~[1,3]~~
Lean-burn Internal Combustion Engine	0.936~~[1,2]~~
Rich-burn Internal Combustion Engine	0.995~~[1,2]~~
Boiler	0.98~~[1]~~
Microturbine or large gas turbine	0.995~~[1]~~
Upgrade and use of gas as CNG/LNG fuel	0.95
Upgrade and injection into natural gas pipeline	0.98[4]

Table A.7. CO_2 Emission Factors for Fossil Fuel Use

Fuel Type	Heat Content	Carbon Content (Per Unit Energy)	Fraction Oxidized	CO_2 Emission Factor (Per Unit Energy)	CO_2 Emission Factor (Per Unit Mass or Volume)
Coal and Coke	**MMBtu / Short ton**	**kg C / MMBtu**		**kg CO_2 / MMBtu**	**kg CO_2 / Short ton**
Anthracite Coal	25.09	28.26	1.00	103.62	2,599.83
Bituminous Coal	24.93	25.49	1.00	93.46	2,330.04
Sub-bituminous Coal	17.25	26.48	1.00	97.09	1,674.86
Lignite	14.21	26.30	1.00	96.43	1,370.32
Unspecified (Residential/ Commercial)	22.05	26.00	1.00	95.33	2,102.29
Unspecified (Industrial Coking)	26.27	25.56	1.00	93.72	2,462.12
Unspecified (Other Industrial)	22.05	25.63	1.00	93.98	2,072.19
Unspecified (Electric Utility)	19.95	25.76	1.00	94.45	1,884.53
Coke	24.80	31.00	1.00	113.67	2,818.93
Natural Gas (By Heat Content)	**Btu / Standard cubic foot**	**kg C / MMBtu**		**kg CO_2 / MMBtu**	**kg CO_2 / Standard cub. ft.**
975 to 1,000 Btu / Std cubic foot	975 – 1,000	14.73	1.00	54.01	Varies
1,000 to 1,025 Btu / Std cubic foot	1,000 – 1,025	14.43	1.00	52.91	Varies
1,025 to 1,050 Btu / Std cubic foot	1,025 – 1,050	14.47	1.00	53.06	Varies
1,050 to 1,075 Btu / Std cubic foot	1,050 – 1,075	14.58	1.00	53.46	Varies
1,075 to 1,100 Btu / Std cubic foot	1,075 – 1,100	14.65	1.00	53.72	Varies
Greater than 1,100 Btu / Std cubic foot	> 1,100	14.92	1.00	54.71	Varies
Weighted U.S. Average	1,029	14.47	1.00	53.06	0.0546
Petroleum Products	**MMBtu / Barrel**	**kg C / MMBtu**		**kg CO_2 / MMBtu**	**kg CO_2 / gallon**
Asphalt & Road Oil	6.636	20.62	1.00	75.61	11.95
Aviation Gasoline	5.048	18.87	1.00	69.19	8.32
Distillate Fuel Oil (#1, 2 & 4)	5.825	19.95	1.00	73.15	10.15
Jet Fuel	5.670	19.33	1.00	70.88	9.57
Kerosene	5.670	19.72	1.00	72.31	9.76
LPG (average for fuel use)	3.849	17.23	1.00	63.16	5.79
Propane	3.824	17.20	1.00	63.07	5.74
Ethane	2.916	16.25	1.00	59.58	4.14
Isobutene	4.162	17.75	1.00	65.08	6.45
n-Butane	4.328	17.72	1.00	64.97	6.70
Lubricants	6.065	20.24	1.00	74.21	10.72
Motor Gasoline	5.218	19.33	1.00	70.88	8.81
Residual Fuel Oil (#5 & 6)	6.287	21.49	1.00	78.80	11.80
Crude Oil	5.800	20.33	1.00	74.54	10.29
Naphtha (<401 deg. F)	5.248	18.14	1.00	66.51	8.31
Natural Gasoline	4.620	18.24	1.00	66.88	7.36
Other Oil (>401 deg. F)	5.825	19.95	1.00	73.15	10.15
Pentanes Plus	4.620	18.24	1.00	66.88	7.36
Petrochemical Feedstocks	5.428	19.37	1.00	71.02	9.18
Petroleum Coke	6.024	27.85	1.00	102.12	14.65
Still Gas	6.000	17.51	1.00	64.20	9.17
Special Naphtha	5.248	19.86	1.00	72.82	9.10
Unfinished Oils	5.825	20.33	1.00	74.54	10.34
Waxes	5.537	19.81	1.00	72.64	9.58

Source: EPA Climate Leaders, Stationary Combustion Guidance (2008), Table B-2 except:
Default CO_2 emission factors (per unit energy) are calculated as: Carbon Content × Fraction Oxidized × 44/12.
Default CO_2 emission factors (per unit mass or volume) are calculated as: Heat Content x Carbon Content × Fraction Oxidized × 44/12× Conversion Factor (if applicable). Heat content factors are based on higher heating values (HHV).

Table A.8. CO_2 Electricity Emission Factors

eGRID subregion acronym	eGRID subregion name	Annual output emission rates	
		(lb CO_2/MWh)	(metric ton CO_2/MWh)*
AKGD	ASCC Alaska Grid	1,232.36	0.559
AKMS	ASCC Miscellaneous	498.86	0.226
AZNM	WECC Southwest	1,311.05	0.595
CAMX	WECC California	724.12	0.328
ERCT	ERCOT All	1,324.35	0.601
FRCC	FRCC All	1,318.57	0.598
HIMS	HICC Miscellaneous	1,514.92	0.687
HIOA	HICC Oahu	1,811.98	0.822
MROE	MRO East	1,834.72	0.832
MROW	MRO West	1,821.84	0.826
NEWE	NPCC New England	927.68	0.421
NWPP	WECC Northwest	902.24	0.409
NYCW	NPCC NYC/Westchester	815.45	0.370
NYLI	NPCC Long Island	1,536.80	0.697
NYUP	NPCC Upstate NY	720.80	0.327
RFCE	RFC East	1,139.07	0.517
RFCM	RFC Michigan	1,563.28	0.709
RFCW	RFC West	1,537.82	0.698
RMPA	WECC Rockies	1,883.08	0.854
SPNO	SPP North	1,960.94	0.889
SPSO	SPP South	1,658.14	0.752
SRMV	SERC Mississippi Valley	1,019.74	0.463
SRMW	SERC Midwest	1,830.51	0.830
SRSO	SERC South	1,489.54	0.676
SRTV	SERC Tennessee Valley	1,510.44	0.685
SRVC	SERC Virginia/Carolina	1,134.88	0.515

Source: U.S. EPA eGRID2007, Version 1.1 Year 2005 GHG Annual Output Emission Rates (December 2008).
* Converted from lbs CO_2/MWh to metric tons CO_2/MWH using conversion factor 1 metric ton = 2,204.62 lbs.

Appendix B Data Substitution – Quantification Methodology

This appendix shows how to calculate GHG 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.

B.1 Missing Data

ARB expects that offset projects will have continuous, uninterrupted data for the entire verification period. However, ARB 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 may be 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

Note: It is conservative to use the upper confidence limit when calculating emissions from the BCS (Equation 5.6); however it is conservative to use the lower confidence limit when calculating the total amount of methane that is destroyed in the BCS Equation 5.10.

Appendix C Offset Project Listing Information

All information, if applicable, must be completed, even if the answer is also provided elsewhere;

1. Offset ~~P~~project ~~N~~name
2. Offset Project Operator or Authorized Project Designee
3. Facility ~~O~~owner
4. Technical ~~C~~consultants
5. Other parties with a material interest
6. Date of form completion
7. Form completed by (name, organization)
8. Offset p~~P~~roject ~~D~~description: 1-2 paragraphs (including type of digester & method of destruction)
9. Offset p~~P~~roject ~~S~~site ~~A~~address (including all governing jurisdictions & lat/lon)
10. Name & address of animal facility (if different from project site)
11. Description of type of facility (e.g. dairy, swine, etc.)
12. Offset p~~P~~roject commencement date
13. Reporting period
14. Have any GHG reductions associated with the offset project ever been registered with or claimed by another registry or program, or sold to a third party prior to our listing? If yes, identify the registry or program (~~V~~vintage and reporting period)
15. Is this offset project being implemented and conducted as the result of any law, statute, regulation, court order, or other legally binding mandate? If yes, explain.

Appendix D Offset Project Data Report Information

1. Offset ~~P~~project ~~N~~name
2. Offset Project Operator or Authorized Project Designee
3. Report ~~D~~date
4. Contact information for Offset Project Operator or Authorized Project Designee
    a. Address, email, phone number
5. Name of ~~I~~individual ~~C~~completing ~~R~~report
6. Reporting ~~P~~period
7. Does offset project meet all local, state, or federal regulatory requirements
8. Offset ~~P~~project ~~C~~commencement ~~D~~date
9. Facility ~~N~~name and ~~L~~location
10. Is all the information in the offset project listing still accurate? If not provide~~d~~ updates.
11. Project ~~B~~baseline ~~E~~emissions
12. Project ~~E~~emissions
13. Total GHG ~~R~~reductions