



California Environmental Protection Agency

AIR RESOURCES BOARD

Compliance Offset Protocol Livestock Projects

Capturing and Destroying Methane from
Manure Management Systems

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Note: All text is new. As permitted by title 2, California Code of Regulations, section 8, for ease of review, underline to indicate adoption has been omitted.

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Table of Contents

Contents

Chapter 1. Purpose and Definitions	5
1.1. Purpose.....	5
1.2. Definitions	5
Chapter 2. Eligible Activities – Quantification Methodology	10
2.1. Project Definition	10
Chapter 3. Eligibility	10
3.1. General Eligibility Requirements.	10
3.2. Location	11
3.3. The Offset Project Operator or Authorized Project Designee.....	12
3.4. Additionality.....	12
3.4.1. Legal Requirement Test	12
3.4.2. Performance Standard Evaluation.....	13
3.5. Offset Project Commencement	13
3.6. Offset Project Crediting Period.....	13
3.7. Regulatory Compliance.....	14
Chapter 4. Offset Project Boundary – Quantification Methodology	14
Chapter 5. Quantifying GHG Emission Reductions – Quantification Methodology ..	17
5.1. Quantifying Baseline Methane Emissions	18
5.2. Quantifying Project Methane Emissions.....	23
5.3. Metered Methane Destruction Comparison.....	28
5.4. Quantifying Project Baseline and Project Carbon Dioxide Emissions	30
Chapter 6. Monitoring	32
6.1. General Monitoring Requirement - Quantification Methodology.....	32
6.2. Biogas Measurement Instrument QA/QC – Quantification Methodology.....	33
6.3. Document Retention	35
6.4. Monitoring Parameters – Quantification Methodology.....	36
Chapter 7. Reporting.....	43
7.1. Listing Requirements	43
7.2. Offset Project Data Report.....	44
Chapter 8. Verification.....	45
Appendix A.....	48

Appendix B.....	61
Equation 5.1: GHG Reductions from Installing a BCS.....	18
Equation 5.2: Modeled Project Baseline Methane Emissions	19
Equation 5.3: Modeled project baseline methane emissions from anaerobic storage treatment systems	20
Equation 5.4: Modeled project baseline methane for non-anaerobic storage/treatment systems	22
Equation 5.5: Project Methane Emissions.....	23
Equation 5.6: Project Methane Emissions from the BCS	24
Equation 5.7: Biogas Volume corrected for Temperature and Pressure	25
Equation 5.8 : Project Methane Emissions from the BCS Effluent Pond.....	26
Equation 5.9: Project Methane Emissions from <i>Non</i> -BCS Related Sources	27
Equation 5.10 : Metered Methane Destruction	29
Equation 5.11: Biogas Volume corrected for Temperature and Pressure	30
Equation 5.12 Baseline Carbon Dioxide Emissions	31
Equation 5.13 Project Carbon Dioxide Emissions	31
Figure 4.1. General Illustration of the Offset Project Boundary	15
Table 4.1. Description of all GHG Sources, GHG Sinks, and GHG Reservoirs.....	15
Table 6.1. Project Monitoring Parameters	37
Table A.1.Livestock Categories and Typical Average Mass (Mass _L)	46
Table A.2. Volatile Solids and Maximum Methane Potential by Livestock Category	46
Table A.3. Biogas Collection Efficiency by Digester Type.....	46
Table A.4. 2008-2010 Volatile Solid (VS _{table})Default Values for Dairy Cows, Heifers, Heifers-Grazing and Cows- Grazing by State (kg/day/1000 kg mass)	47
Table A.5. IPCC 2006 Methane Conversion Factors by Manure Management System Component/Methane Source‘S’	49
Table A.6. Biogas Destruction Efficiency Default Values by Destruction Device.....	54
Table A.7. CO2 Emission Factors for Fossil Fuel Use	55
Table A.8. CO2 Electricity Emission Factors.....	57
Table A.9. Volatile Solids Removed Through Solids Separation.....	58
Table A.10. Baseline Assumptions for Greenfield Projects*	58
Table B.1. Missing Data	60

Chapter 1. Purpose and Definitions

1.1. Purpose

- (a) The purpose of the Compliance Offset Protocol Livestock Projects (protocol) is to quantify greenhouse gas emission reductions associated with the installation of a BCS for manure management on dairy cattle and swine farms that would otherwise be vented into the atmosphere as a result of livestock operations from those farms.
- (b) AB 32 exempts quantification methodologies from the Administrative Procedure Act¹; 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.

1.2. Definitions

- (a) For the purposes of this protocol, the following definitions apply:
 - (1) “Aerobic Treatment” means 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.
 - (2) “Anaerobic” means pertaining to or caused by the absence of oxygen.
 - (3) “Anaerobic Digester” or “Digester” means a large containment vessel or covered lagoon that collects and anaerobically digests animal excreta with or without straw. Digesters are designed and operated for waste

¹ Health and Safety Code section 38571

stabilization by the microbial reduction of complex organic compounds to CO₂ and CH₄, which is captured and flared or used as a fuel.

- (4) “Baseline Emissions,” see “Project Baseline Emissions”
- (5) “Biogas Control System” or “BCS” commonly referred to as a digester, is a system that is 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.
- (6) “Biogenic CO₂ Emissions,” for the purposes of this protocol, means CO₂ 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.
- (7) “Burned for Fuel” means the dung and urine that are excreted on fields. The sun dried dung cakes are burned for fuel.
- (8) “Cap-and-Trade Regulation” or “Regulation” means ARB’s regulation establishing the California Cap on Greenhouse Gas Emissions and Market-Based Compliance Mechanisms set forth in title 17, California Code of Regulations Chapter 1, Subchapter 10, article 5 (commencing with section 95800).
- (9) “Cattle and Swine Deep Bedding” means that 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 is also known as a “bedded pack manure” management system and may be combined with a dry lot or pasture.
- (10) “Centralized Digester” means a digester that integrates waste from more than one livestock operation.
- (11) “Composting – Intensive Windrow” means composting in windrows with regular (at least daily) turning for mixing and aeration.
- (12) “Composting – In-Vessel” means composting, typically in an enclosed channel, with forced aeration and continuous mixing.
- (13) “Composting – Passive Windrow” means composting in windrows with infrequent turning for mixing and aeration.

- (14) “Composting – Static Pile” means composting in piles with forced aeration but no mixing.
- (15) “Daily Spread” means manure that is routinely removed from a confinement facility and is applied to cropland or pasture within 24 hours of excretion.
- (16) “Dry Lot” means a paved or unpaved open confinement area without any significant vegetative cover where accumulating manure may be removed periodically.
- (17) “Emission Factor” has the same definition as provided in section 95102 of the Mandatory Reporting Regulation.
- (18) “Enclosed Vessel” means a complete mix, fixed film, or plug-flow digester that is topped by a cover (e.g. hardened or dual membrane flexible) that provides a complete enclosure to the digester itself. A digester cover design that does not meet this exact definition must offer verifiable proof that it achieves the same biogas capture efficiency as an enclosed vessel cover would.
- (19) “Flare” has the same definition as provided in section 95102 of the Mandatory Reporting Regulation.
- (20) “Greenfield Livestock Project” means a project that is implemented at a new livestock facility that has no prior manure management system.
- (21) “Initial Start-up Period” means the period between post-system installation and pre-project commencement. After the installation of the project’s BCS, the Offset Project Operator or Authorized Project Designee may run, tune, and test the system to ensure its operational quality.
- (22) “Liquid Slurry” means manure that is stored as excreted or with some minimal addition of water in either tanks or earthen ponds outside the animal housing, usually for periods of less than one year.
- (23) “Livestock Project” means installation of a BCS that, in operation, causes a decrease in GHG emissions from the baseline scenario through destruction of the methane component of biogas.
- (24) “Mandatory Reporting Regulation” or “MRR” means ARB’s regulation establishing the Mandatory Reporting of Greenhouse Gas Emissions set

forth in title 17, California Code of Regulations Chapter 1, Subchapter 10, article 2 (commencing with section 95100).

- (25) “Mobile Combustion” means emissions from the transportation of materials, products, waste, and employees that result from the combustion of fuels in company owned or controlled mobile combustion sources.
- (26) “Pasture/Range/Paddock” means that the manure from pasture and range grazing animals is allowed to lie as deposited, and is not managed.
- (27) “Pit Storage Below Animal Confinements” means the 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 of less than one year.
- (28) “Project Baseline Emissions” or “Baseline Emissions” means the GHG emissions within the Offset Project Boundary that would have occurred if not for the installation of the BCS.
- (29) “Registry offset credits” means the offset credits defined in section 95802 of the Regulation and whose issuance is described in section 95980 and section 95980.1 of the Regulation.
- (30) “Solid Storage” means the storage of manure, typically for a period of several months, in unconfined piles or stacks. Manure is able to be stacked because there is a sufficient amount of bedding material or loss of moisture by evaporation.
- (31) “Standard Conditions” or “Standard Temperature and Pressure” or “STP” means, for the purposes of this protocol, 60 degrees Fahrenheit and 14.7 pounds per square inch absolute.
- (32) “Standard Cubic Foot” or “scf” means, for the purposes of this protocol, a measure of quantity of gas equal to a cubic foot of volume at 60 degrees Fahrenheit and 14.7 pounds per square inch (1atm) pressure.
- (33) “Stationary Combustion Source” means a stationary source of emissions from the production of electricity, heat, or steam that result from the combustion of fuels in boilers, furnaces, turbines, kilns, and other facility equipment.

- (34) “Uncovered Anaerobic Lagoon” means a type of liquid storage system that is 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, 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.
- (35) “Van’t Hoff-Arrhenius Factor” means the proportion of volatile solids that are biologically available for conversion to methane based on the monthly temperature of the system.
- (b) For terms not defined in subchapter 1.2(a) of this protocol, the definitions in section 95802 of the Regulation apply.
- (c) Acronyms. For purposes of this protocol, the following acronyms apply:
- (1) “AB 32” means The Global Warming Solutions Act of 2006.
 - (2) “APA” means Administrative Procedure Act.
 - (3) “ARB” means California Air Resources Board.
 - (4) “BCS” means biogas control system.
 - (5) “BDE” means biogas destruction efficiency.
 - (6) “CH₄” means methane.
 - (7) “CITSS” means Compliance Instrument Tracking System Service.
 - (8) “CNG” means condensed natural gas.
 - (9) “CO₂” means carbon dioxide.
 - (10) “GHG” means greenhouse gas.
 - (11) “GWP” means global warming potential.
 - (12) “ID” means identification.
 - (13) “IPCC” means Intergovernmental Panel on Climate Change.
 - (14) “kg” means kilogram.
 - (15) “lb” means pound.
 - (16) “LNG” means liquefied natural gas.
 - (17) “MMBtu” means one million British thermal units.
 - (18) “MS” means management system.

- (19) “mt” means metric ton.
- (20) “N₂O” means nitrous oxide.
- (21) “NG” means natural gas.
- (22) “QA/QC” means quality assurance/quality control.
- (23) “R” mean Rankine.
- (24) “scf” means standard cubic feet.
- (25) “SSR” means GHG sources, GHG sinks, and GHG reservoirs.
- (26) “STP” means standard temperature and pressure.
- (27) “TAM” means typical average mass.
- (28) “VS” means volatile solids.

Chapter 2. Eligible Activities – Quantification Methodology

This protocol defines a set of activities designed to reduce GHG emissions that result from anaerobic manure treatment at dairy cattle and swine farms. Projects that install a BCS that captures and destroys methane gas from anaerobic manure treatment and/or storage facilities on livestock operations are eligible.

2.1. Project Definition

- (a) The BCS 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.
- (b) Captured biogas can be destroyed on-site, transported for off-site use (e.g. through gas distribution or transmission pipeline), or used to power vehicles.
- (c) A centralized digester that integrates waste from more than one livestock operation meets the definition of an offset project.

Chapter 3. Eligibility

In addition to the offset project eligibility criteria and the regulatory program requirements set forth in subarticle 13 of the Regulation, livestock offset projects must adhere to the eligibility requirements below:

3.1. General Eligibility Requirements.

- (a) Offset projects that use this protocol must:

- (1) Involve the installation and operation of a device, or set of devices, associated with the capture and destruction of methane;
 - (2) Capture methane that would otherwise be emitted to the atmosphere; and
 - (3) Destroy the captured methane through an eligible end-use management option per subchapter 3.4 of this protocol.
- (b) Offset Project Operators or, if applicable, Authorized Project Designees using this protocol must:
- (1) Provide the listing information required by section 95975 of the Regulation and subchapter 7.1 of this protocol;
 - (2) Monitor GHG emission SSRs within the GHG assessment boundary as delineated in chapter 4 pursuant to the requirements of Chapter 6 of this protocol;
 - (3) Quantify GHG emission reductions pursuant to Chapter 5 of this protocol;
 - (4) Prepare and submit the Offset Project Data Report for each reporting period that include the information requirements in chapter 7 of this protocol; and
 - (5) Obtain offset verification services from an ARB-accredited offset verification body in accordance with section 95977 of the Regulation and Chapter 8 of this protocol.

3.2. Location

- (a) Only projects located in the United States and United States' territories are eligible under this protocol.
- (b) 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.

3.3. The Offset Project Operator or Authorized Project Designee

- (a) The Offset Project Operator or Authorized Project Designee is responsible for project listing, monitoring, reporting, and verification.
- (b) The Offset Project Operator or Authorized Project Designee must submit the information required by subarticle 13 of the Regulation and in subchapters 7.1 and 7.2 of this protocol.
- (c) The Offset Project Operator must have legal authority to implement the offset project.

3.4. Additionality

Offset projects must meet the additionality requirements of section 95973(a)(2) of the Regulation, as well as the requirements in this protocol. Eligible offsets must be generated by projects that yield surplus GHG reductions that exceed any GHG reductions otherwise required by law or regulation or any GHG reduction that would otherwise occur in a conservative business-as-usual scenario. These requirements are assessed through the Legal Requirement Test in subchapter 3.4.1. and the Performance Standard Evaluation in subchapter 3.4.2. of this protocol.

3.4.1. Legal Requirement Test

- (a) Emission reductions achieved by a livestock project must exceed those required by any law, regulation, or legally binding mandate, as required by sections 95973(a)(2)(A) and 95975(n) of the Regulation.
- (b) The following legal requirement test applies to all livestock projects:
 - (1) If no law, regulation, or legally binding mandate requiring the destruction of methane at which the project is located exists, all emission reductions resulting from the capture and destruction of methane are considered to not be legally required, and therefore eligible for crediting under this protocol.
 - (2) If any law, regulation, or legally binding mandate requiring the destruction of methane at which the project is located exists, only emission reductions resulting from the capture and destruction of methane that are in excess of what is required to comply with those laws, regulations, and/or legally binding mandates are eligible for crediting under this protocol.

3.4.2. Performance Standard Evaluation

- (a) Emission reductions achieved by a livestock project must exceed those likely to occur in a conservative business-as-usual scenario.
- (b) The performance standard evaluation for existing farms is satisfied if the depth of the anaerobic lagoons or ponds prior to the offset project's commencement were sufficient to prevent algal oxygen production and create an oxygen-free bottom layer; which means at least 1 meter in depth at the shallowest area.
- (c) The performance standard evaluation for a greenfield livestock project is satisfied only if uncontrolled anaerobic storage and/or treatment of manure is common practice in the industry and geographic region where the offset project is located as determined by ARB. Greenfield projects must use the baseline assumptions in Table A.10.

3.5. Offset Project Commencement

- (a) For this protocol, offset project commencement is defined as the date at which the offset project's BCS becomes operational.
- (b) 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. An initial start-up period must not exceed nine months. The commencement date, which follows the initial start-up period, is defined as the date that the BCS becomes operational.
- (c) Pursuant to section 95973(a)(2)(B) of the Regulation, compliance offset projects must have an offset project commencement date after December 31, 2006.

3.6. Offset Project Crediting Period

- (a) For this protocol, the crediting period for an eligible project is ten reporting periods from the first day of the first reporting period as identified in the first verified Offset Project Data Report received by ARB or an Offset Project Registry approved pursuant to section 95986 of the Regulation.
- (b) The upgrade of a BCS at an existing project continues the original crediting period and retains the original baseline scenario.
- (c) Switching manure from an existing project to a different BCS, including a centralized BCS, continues the crediting period of the project with the earliest commencement date. For a centralized BCS, only livestock manure that meets

the relevant eligibility requirements of chapter 3 of this protocol is eligible for crediting under this protocol.

3.7. Regulatory Compliance

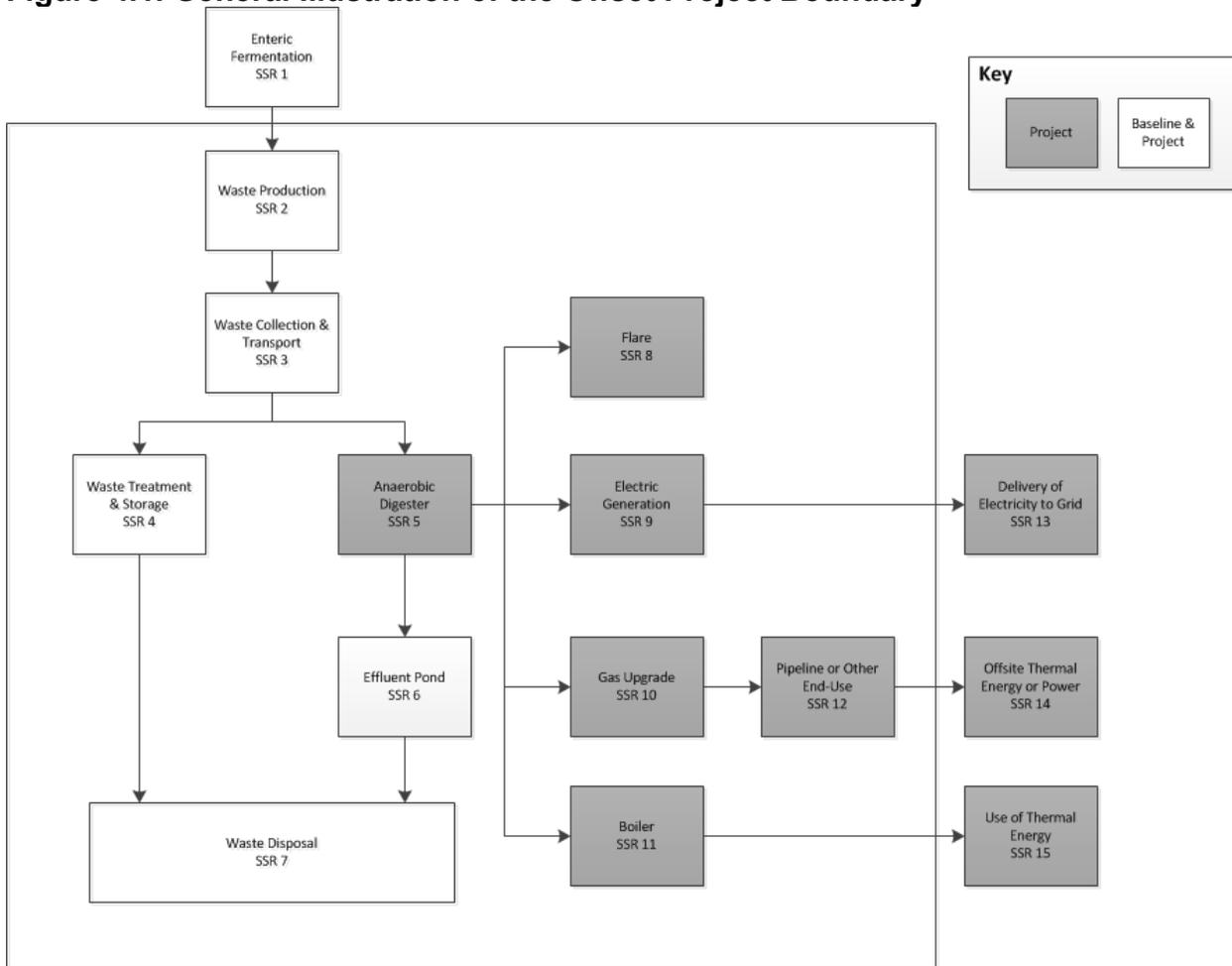
An offset project must meet the regulatory compliance requirements set forth in section 95973(b) of the Regulation.

Chapter 4. Offset Project Boundary – Quantification Methodology

The GHG assessment boundary, or offset project boundary, delineates the SSRs that must be included or excluded when quantifying the net change in emissions associated with the installation and operation of a device, or set of devices, associated with the capture and destruction of methane. The following apply to all livestock projects regarding offset project boundaries:

- (a) Figure 4.1 illustrates the GHG assessment boundary for livestock projects, indicating which SSRs are included or excluded from the Offset Project Boundary.
 - (1) All SSRs within the bold line are included and must be accounted for under this protocol.
 - (2) SSRs in unshaded boxes are relevant to the baseline and project emissions.
 - (3) SSRs in shaded boxes are relevant only to the project emissions.

Figure 4.1. General Illustration of the Offset Project Boundary



(b) Table 4.1. Description of all GHG Sources, GHG Sinks, and GHG Reservoirs lists the SSRs for livestock projects, indicating which gases are included or excluded from the offset project boundary.

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

SSR	GHG Source	GHG	Relevant to Baseline (B) or 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 ₂ O	B, P	Excluded
		CO ₂	B, P	Included
	CH ₄	Excluded		
	Emissions from mobile and stationary support equipment	N ₂ O		Excluded

SSR	GHG Source	GHG	Relevant to Baseline (B) or Project (P)	Included/ 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 ₂ O		Excluded
	Vehicle emissions (e.g. for centralized digesters)	CO ₂		Included
		CH ₄		Excluded
		N ₂ O		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 ₂ O		Excluded
	Emissions from support equipment	CO ₂		Included
		CH ₄		Excluded
		N ₂ O		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	B, P	Included
		N ₂ O		Excluded
7	Emissions from land application	N ₂ O	B, P	Excluded
	Vehicle emissions for land application and/or off-site transport	CO ₂	B, P	Included
		CH ₄		Excluded
		N ₂ O		Excluded
8	Emissions from combustion during flaring, including emissions from incomplete combustion of biogas	CO ₂	P	Excluded
		CH ₄		Included
		N ₂ O		Excluded
9	Emissions from combustion during electric generation, including incomplete combustion of biogas	CO ₂	P	Excluded
		CH ₄		Included
		N ₂ O		Excluded
10	Emissions from equipment upgrading biogas for pipeline injection or use as CNG/LNG fuel	CO ₂	P	Included
		CH ₄		Excluded
		N ₂ O		Excluded
11	Emissions from combustion at boiler including emissions from incomplete combustion of biogas	CO ₂	P	Excluded
		CH ₄		Included
		N ₂ O		Excluded
12	Emissions from combustion of biogas by end user of pipeline or CNG/LNG, including incomplete combustion	CO ₂	P	Excluded
		CH ₄		Included
		N ₂ O		Excluded

SSR	GHG Source	GHG	Relevant to Baseline (B) or Project (P)	Included/ Excluded
13	Delivery and use of project electricity to grid	CO ₂	P	Excluded
		CH ₄		
		N ₂ O		
14	Off-site thermal energy or power	CO ₂	P	Excluded
		CH ₄		
		N ₂ O		
15	Use of project-generated thermal energy	CO ₂	P	Excluded
		CH ₄		
		N ₂ O		
16	Project construction and decommissioning emissions	CO ₂	P	Excluded
		CH ₄		
		N ₂ O		

Chapter 5. Quantifying GHG Emission Reductions – Quantification Methodology

- (a) GHG emission reductions from a livestock project are quantified by comparing actual project emissions to baseline emissions within the offset project boundary.
- (b) The Offset Project Operator or, if applicable, Authorized Project Designee must use the specific calculation methods provided in this protocol to determine baseline and project GHG emissions.
- (c) GHG emission reductions must be quantified over an entire reporting period. Pursuant to section 95802(a) of the Regulation, the initial reporting may consist of 6 to 24 consecutive months, and all subsequent reporting periods consist of 12 consecutive months.
- (d) Measurements used to quantify emission reductions must be corrected to standard conditions of 60°F and 14.7 pounds per square inch (1 atm).
- (e) Global warming potential values must be determined consistent with the definition of Carbon Dioxide Equivalent in MRR section 95102(a).
- (f) GHG emission reductions for a reporting period (ER) must be quantified using Equation 5.1 by summing two selections:
- (1) The smaller of:
 - (A) the project methane emission (PE_{CH_4}) subtracted from modeled project baseline methane emissions ($BE_{CH_4 Mod}$); or
 - (B) the metered and destroyed methane ($CH_{4 meter}$); and

(2) The smaller of:

- (A) project carbon dioxide emissions (PE_{CO_2}) subtracted from the project baseline carbon dioxide emissions (BE_{CO_2}); or
- (B) zero.

Equation 5.1: GHG Reductions from Installing a BCS

$$ER = \text{MIN}[(BE_{CH_4 \text{ Mod}} - PE_{CH_4}), CH_{4 \text{ meter}}] + \text{MIN}[(BE_{CO_2} - PE_{CO_2}), 0]$$

<i>Where,</i>		<u>Units</u>
$BE_{CH_4 \text{ Mod}}$	= Modeled baseline methane emissions during the reporting period	mtCO ₂ e
PE_{CH_4}	= Total project methane emissions during the reporting period	mtCO ₂ e
$CH_{4 \text{ meter}}$	= Aggregated quantity of methane collected and destroyed during the reporting period	mtCO ₂ e
BE_{CO_2}	= Total baseline anthropogenic CO ₂ emissions from electricity consumption and mobile and stationary combustion that would have occurred in the absence of the project	mtCO ₂ e
PE_{CO_2}	= Total project anthropogenic CO ₂ emissions from electricity consumption and mobile and stationary combustion sources resulting from project activity	mtCO ₂ e

5.1. Quantifying Baseline Methane Emissions

- (a) Total modeled project baseline methane emissions for a reporting period ($BE_{CH_4 \text{ Mod}}$) must be estimated by using equation 5.2 and summing the baseline methane emissions for all SSRs which table 4.1 identifies as included within the project boundary.
- (b) Baseline emissions represent the GHG emission that would have occurred in the absence of the BCS. Baseline emissions are calculated based on the manure management system in place prior to the installation of the BCS. Baseline emissions are recalculated for each reporting period and represent the emissions that would have occurred with the previous manure management system operated under the current conditions.

Equation 5.2: Modeled Project Baseline Methane Emissions

$$BE_{CH4Mod} = \sum_{AS} BE_{CH4,AS} + \sum_{non-AS} BE_{CH4,non-AS}$$

<i>Where,</i>		<u>Units</u>
BE_{CH4}	= Total project baseline methane emissions for a reporting period.	mtCO ₂ e
$BE_{CH4,AS}$	= Total project baseline methane emissions from anaerobic storage/treatment systems by livestock category for a reporting period	mtCO ₂ e
$BE_{CH4,non-AS}$	= Total project baseline methane emissions from non-anaerobic storage/treatment systems by livestock category for a reporting period	mtCO ₂ e
AS	= Anaerobic storage/treatment systems	
Non-AS	= Non-anaerobic storage/treatment systems	

- (c) Baseline modeled methane emission from anaerobic storage/treatment systems ($BE_{CH4,AS,L}$) must be quantified using equation 5.3.
- (d) Methane producing capacity for each livestock category ($B_{O,L}$) and volatile solids produced (VS_{table}) must use default values from tables A.2 and A.4 as applicable.
- (e) The average monthly population for each livestock category ($P_{L,i}$) must use site-specific data monitored and recorded at least monthly.
- (f) The fraction of volatile solids ($MS_{AS,L}$) sent to each anaerobic storage/treatment system for each livestock category represents the percent of manure that would be sent to (managed by) the anaerobic manure storage/treatment systems, taking into account any volatile solids removed by solid separation equipment, in the project baseline case, as if the BCS was never installed. Site-specific data must be used if available. If site-specific data is unavailable, values from table A.9 can be used to calculate $MS_{AS,L}$.
- (g) The number of reporting days in the reporting month ($RD_{rm,i}$) must be calculated by subtracting the number of days not in the reporting period for the reporting month and the number of days the project is ineligible to report from the total number of reporting days in the reporting month. Ineligible days include, but are not limited to, days with missing data beyond what is allowed to be substituted according to the methods in appendix B.
- (h) The annual average live weight of the animals ($Mass_L$), per livestock category, must be taken from site-specific livestock mass data. If site-specific data are unavailable, Typical Average Mass (TAM) values from table A.1 must be used.

- (i) The monthly average ambient temperature (T_2) in Kelvin must be obtained from the closest weather station, with available data, located in the same air basin, if applicable.
- (j) If the volatile solids retention time in the anaerobic storage/treatment system is less than or equal to 30 days, then the volatile solids retained in the system from the previous month ($VS_{avail, AS, L, i-1} - VS_{deg, AS, L, i-1}$) must be set to zero.
- (k) For the month following the complete drainage and cleaning of solid buildup from the anaerobic storage/treatment system, the volatile solids retained in the system from the previous month ($VS_{avail, AS, L, i-1} - VS_{deg, AS, L, i-1}$) must be set to zero.

Equation 5.3: Modeled project baseline methane emissions from anaerobic storage treatment systems

$$BE_{CH_4, AS} = \sum_{L, i} (VS_{deg, AS, L, i} \times B_{0, L}) \times 0.68 \times 0.001 \times GWP_{CH_4}$$

<i>Where,</i>		<u>Units</u>
$BE_{CH_4, AS}$	= Total project baseline methane emissions from anaerobic manure storage/treatment systems for a reporting period	mtCO ₂ e
$VS_{deg, AS, L, i}$	= Monthly 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' from table A.2	m ³ CH ₄ /kg of VS
0.68	= Density of methane (1 atm, 60°F)	kg/m ³
0.001	= Conversion factor from kg to mt	
GWP_{CH_4}	= Global warming potential of methane	
L	= Livestock category	
i	= Months in the reporting period	

With:

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

<i>Where,</i>		<u>Units</u>
$VS_{deg, AS, L, i}$	= Monthly volatile solids degraded by anaerobic manure storage/treatment system 'AS' by livestock category 'L'	kg dry matter
$VS_{avail, AS, L, i}$	= Monthly volatile solids available for degradation from anaerobic manure storage/treatment system 'AS' by livestock category 'L'	kg dry matter
f	= Van't Hoff-Arrhenius factor	
i	= Months in the reporting period	

And:

$$VS_{avail, AS, L, i} = (VS_L \times P_{L, i} \times MS_{AS, L} \times RD_{rm, i} \times 0.8) + (VS_{avail, AS, L, i-1} - VS_{deg, AS, L, i-1})$$

<i>Where,</i>		<u>Units</u>
$VS_{avail,AS,L}$	= Monthly volatile solids available for degradation in anaerobic storage/treatment system 'AS' by livestock category 'L'	kg dry matter
VS_L	= Volatile solids produced by livestock category 'L' on a dry matter basis	kg/ animal/ day
$P_{L,i}$	= Monthly average population of livestock category 'L'	
$MS_{AS,L}$	= Fraction of volatile solids sent to (managed in) anaerobic manure storage/treatment system 'AS' from livestock category 'L'	Fraction (0-1)
$RD_{m,i}$	= Number of reporting days in the reporting month	days
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
And:		
$VS_L = VS_{table} \times \frac{Mass_L}{1000}$		
<i>Where,</i>		<u>Units</u>
VS_L	= Volatile solid excretion on a dry matter weight basis	kg/ animal/ day
VS_{table}	= Volatile solid excretion from table A.2 or A.4	kg/ day/ 1000kg
$Mass_L$	= Average live weight for livestock category 'L'; if site-specific data is unavailable, use values from table A.1	kg
And:		
$f = MIN \left(\exp \left[\frac{E(T_2 - T_1)}{RT_1 T_2} \right], 0.95 \right)$		
<i>Where,</i>		<u>Units</u>
f	= 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

- (l) Modeled baseline methane emissions from non-anaerobic storage/treatment systems ($BE_{CH_4,non-AS,L}$) must be quantified using equation 5.4.
- (m) The fraction of volatile solids ($MS_{non-AS,L}$) sent to each non-anaerobic storage/treatment system for each livestock category represents the fraction of manure that would be sent to (managed by) the non-anaerobic manure storage/treatment systems, taking into account any volatile solids removed by

solid separation equipment, in the project baseline case, as if the BCS was never installed. Site-specific data must be used if available. If site-specific data is unavailable, values from table A.9 must be used to calculate $MS_{non-AS,L}$.

- (n) The number of reporting days in the reporting period (RD_{rp}) must be calculated by subtracting the number of days the project is ineligible to report from the total number of reporting days in the reporting period. Ineligible days would include, but are not limited to, days with missing data beyond what is allowed to be substituted according to the methods in appendix B.
- (o) The methane conversion factor for the non-anaerobic storage/treatment (MCF_{non-AS}) represents the non-anaerobic systems in place prior to BCS installation and must be obtained from table A.5 for the appropriate system type and average annual temperature ($^{\circ}C$).

Equation 5.4: Modeled project baseline methane for non-anaerobic storage/treatment systems

$$BE_{CH4,non-AS} = \sum_{L,i} (P_{L,i} \times MS_{non-AS,L} \times VS_L \times RD_{rm} \times MCF_{non-AS} \times B_{0,L}) \times 0.68 \times 0.001 \times GWP_{CH4}$$

<i>Where,</i>		<u>Units</u>
$BE_{CH4,non-AS}$	= Total project baseline methane emissions from non-anaerobic storage/treatment systems for a reporting period, expressed in carbon dioxide equivalent	mtCO ₂ e
P_L	= Monthly average population of livestock category 'L'	
$MS_{non-AS,L}$	= Fraction of volatile solids from livestock category 'L' managed in non-anaerobic storage/treatment systems	Fraction (0-1)
VS_L	= Volatile solids produced by livestock category 'L' on a dry matter basis	kg/ animal/ day
RD_{rm}	= Number of reporting days in the current reporting month	days
MCF_{non-AS}	= Methane conversion factor for non-anaerobic storage/treatment system 'S' from table A.5.	Fraction (0-1)
$B_{0,L}$	= Maximum methane producing capacity for manure for livestock category 'L' from table A.2	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 mt	
GWP_{CH4}	= Global warming potential of methane	
i	= Months in the reporting period	

With:

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

Where, Units

VS_L	=	Volatile solid excretion on a dry matter weight basis	kg/ animal/ day
VS_{table}	=	Volatile solid excretion from tables A.2 and A.4	kg/ day/ 1000kg
$Mass_L$	=	Average live weight for livestock category 'L'	kg

5.2. Quantifying Project Methane Emissions

- (a) Project methane emissions must be quantified for each reporting period.
- (b) Project methane emissions for a reporting period (PE_{CH_4}) must be quantified by using equation 5.5 and summing the project methane emissions for all SSRs which table 4.1 identifies as included within the project boundary.

Equation 5.5: Project Methane Emissions

$$PE_{CH_4} = (PE_{CH_4, BCS} + PE_{CH_4, EP} + PE_{CH_4, non-BCS}) \times GWP_{CH_4}$$

Where,

		<u>Units</u>
PE_{CH_4}	= Total project methane emissions for the reporting period	mtCO ₂ e
$PE_{CH_4, BCS}$	= Methane emissions from the BCS	mtCH ₄
$PE_{CH_4, EP}$	= Methane emissions from the BCS effluent pond	mtCH ₄
$PE_{CH_4, non-BCS}$	= Methane emissions from sources in the waste treatment and storage category other than the BCS and associated effluent	mtCH ₄
GWP_{CH_4}	= Global warming potential of methane	

- (c) Project methane emissions from the BCS ($PE_{CH_4, BCS}$) must be quantified using Equation 5.6.
- (d) The quarterly methane concentration (C_{CH_4}) is used for the entire month in which it is taken and for all subsequent months until a new methane concentration is taken. A weighted average of more frequent samples may also be used.
- (e) A site-specific biogas destruction efficiency (BDE_j) of each device must be used when available, and when the destruction device is not listed in table A.6. If a site-specific methane destruction efficiency for devices listed in table A.6 is not available, then the default value from table A.6 must be used. Site-specific methane destruction efficiencies require prior written approval from the Executive Officer.
- (f) Biogas flow to an inoperable device must be counted as a separate device with a biogas destruction efficiency (BDE_j) of zero when calculating the fractional

monthly weighted average destruction efficiency of devices used during the month ($BDE_{i,weighted}$).

- (g) Biogas capture efficiencies (BCE) must be taken from or calculated according to table A.3.
- (h) All volume flows (F) must come from the monitored project-specific flow data corrected to standard conditions.
- (i) The maximum biogas storage of the BCS system (MS_{BCS}) must be calculated using project-specific information and design documentation.
- (j) The number of days for each uncontrolled venting (t_k) must be monitored and recorded at least daily from the time of discovery.
- (k) The number of days for each uncontrolled venting (t_k) must date back to the last field check date without any uncontrolled venting events.

Equation 5.6: Project Methane Emissions from the BCS

$$PE_{CH_4,BCS} = \sum_i \left[CH_{4\text{ meter},i} \times \left(\left(\frac{1}{BCE} \right) - BDE_{i,weighted} \right) + CH_{4\text{ vent},i} \right]$$

<i>Where,</i>		<u>Units</u>
$PE_{CH_4,BCS}$	= Methane emissions from the BCS	mtCH ₄
$CH_{4\text{ meter},i}$	= Quantity of methane collected and metered in month <i>i</i>	mtCH ₄ / month
BCE	= Fraction of monthly methane collected by the BCS from table A.3	fraction (0-1)
$BDE_{i,weighted}$	= Monthly weighted average of all fractional destruction efficiencies of devices used in month <i>i</i> .	fraction (0-1)
$CH_{4\text{ vent},i}$	= The monthly quantity of methane that is vented to the atmosphere due to BCS venting events	mtCH ₄ / month
<i>i</i>	= Months in the reporting period	

With:

$$BDE_{i,weighted} = \frac{\sum_j (F_{j,i} \times BDE_j)}{\sum_j F_{Fj,i}}$$

<i>Where:</i>		<u>Units</u>
<i>j</i>	= Destruction devices	
$F_{j,i}$	= Volume of biogas in month <i>i</i> sent to destruction device <i>j</i>	scf
BDE _{<i>j</i>}	= Biogas destruction efficiency of device <i>j</i>	fraction (0-1)

And:

$$CH_{4\text{ meter},i} = F_i \times C_{CH_4} \times 0.0423 \times 0.000454$$

<i>Where,</i>		<u>Units</u>
C_{CH_4}	= Quarterly methane concentration	fraction (0-1)
F_i	= Volume of biogas from the digester in month <i>i</i>	scf

And:

$$CH_4_{vent,i} = \sum_k ((F_{pw,k} \times t_k + MS_{BCS}) \times C_{CH_4}) \times 0.04230 \times 0.00454$$

Where,

		<u>Units</u>
$F_{pw,k}$	= The average daily biogas production from the digester for the 7 days preceding the venting event k	scf/day
t_k	= The number of days for each uncontrolled venting event k from the BCS system (can be a fraction)	days
MS_{BCS}	= Maximum biogas storage of the BCS system	scf
C_{CH_4}	= Quarterly methane concentration	fraction (0-1)
0.04230	= Standard density of methane	lb CH ₄ /scf
0.000454	= Conversion factor from lb to mt	CH ₄ mt/lb

- (l) If gas flow metering equipment does not internally correct gas flow volumes to standard conditions, then equation 5.7 must be applied to the volume of biogas prior to calculating project methane emissions from the BCS in equation 5.6.

Equation 5.7: Biogas Volume corrected for Temperature and Pressure

$$F_{corrected,y} = F_{meas,y} \times \frac{519.67}{T_{meas,y}} \times \frac{P_{meas,y}}{1.00}$$

Where:

		<u>Units</u>
$F_{corrected,y}$	= Corrected volume of biogas for time interval y, adjusted to 60 °F and 1 atm	scf
$F_{meas,y}$	= Measured volume of biogas for time interval y	cf
$T_{meas,y}$	= Measured temperature of the biogas for time interval y, °R=°F+459.67	°R
$P_{meas,y}$	= Measured pressure of the biogas for the time interval y	atm

- (m) Project methane emissions from the BCS effluent pond ($PE_{CH_4,ep}$) must be quantified using equation 5.8.
- (n) Methane producing capacity for each livestock category ($B_{O,L}$) and volatile solids produced (VS_{table}) must use default values from tables A.2 and A.4 as applicable.
- (o) The number of reporting days in the reporting period (RD_{rp}) must be calculated as the total number of reporting days in the reporting period.
- (p) The methane conversion factor for the effluent pond (MCF_{ep}) must be obtained from table A.5 using the liquid/slurry system type and appropriate average annual temperature (°C).
- (q) The fraction of volatile solids ($MS_{L,BCS}$) sent to the BCS for each livestock category represents the fraction of manure that was sent to (managed by) the

BCS, taking into account any volatile solids removed by solid separation equipment. Site-specific data must be used if available. If site-specific data is unavailable, then values from table A.9 must be used to calculate $MS_{L,BCS}$.

- (r) The average monthly population ($P_{L,i}$) must use site-specific data monitored and recorded at least monthly.
- (s) The number of reporting days in the reporting month ($RD_{rm,i}$) must be calculated by subtracting the number of days not in the reporting period for the reporting month.
- (t) The annual average live weight of the animals ($Mass_L$), per livestock category, must be taken from site-specific livestock mass data if the data are available. If site-specific data is unavailable, Typical Average Mass (TAM) values from table A.1 must be used.

Equation 5.8 : Project Methane Emissions from the BCS Effluent Pond(s)

$$PE_{CH_4,EP} = \sum_I (VS_{ep} \times RD_{rp} \times 0.68 \times MCF_{ep} \times 0.001)$$

<i>Where,</i>		<u>Units</u>
$PE_{CH_4, EP}$	= Methane emissions from the effluent pond	mtCH ₄
I	= Number of effluent ponds	
VS_{ep}	= Volatile solid to effluent pond	kg/day
RD_{rp}	= Reporting days in the reporting period	days
0.68	= Density of methane (1 atm, 60°F)	kg/m ³
MCF_{ep}	= Methane conversion factor from table A.4	fraction (0-1)
0.001	= Conversion factor from kg to mt	

With:

$$VS_{ep} = \sum_L (VS_L \times P_L \times B_{O,L} \times MS_{L,BCS}) \times 0.3$$

<i>Where,</i>		<u>Units</u>
VS_L	= VS produced by livestock category 'L' on a dry matter basis.	kg/ animal/ day
P_L	= Average population of livestock category 'L' (based on monthly population data) for a given reporting period	
$B_{O,L}$	= Maximum methane producing capacity for livestock category 'L' (of VS dry matter)	m ³ CH ₄ /kg
$MS_{L,BCS}$	= Fraction of manure from livestock category 'L' that is managed in the BCS	fraction (0-1)
0.3	= Default value representing the amount of VS that exits the digester as a percentage of the VS entering the digester	

And:

$$P_L = \frac{\sum_i (RD_{rm,i} \times P_{L,i})}{RD_{rp}}$$

Where,

$RD_{rm,i}$	=	Reporting days in the reporting month	<u>Units</u> days
$P_{L,i}$	=	Monthly average population of livestock category 'L'	
RD_{rp}	=	Reporting days in the reporting period	days

And:

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

Where,

VS_L	=	Volatile solid excretion on a dry matter weight basis	<u>Units</u> kg/ animal/ day
VS_{table}	=	Volatile solid excretion from tables A.2 and A.4	kg/ day/ 1000kg
$Mass_L$	=	Average live weight for livestock category 'L',	kg

- (u) Project methane emissions from manure management system components other than the BCS and the BCS effluent pond ($PE_{CH_4,nBCS}$) must be quantified using equation 5.9.
- (v) The methane conversion factor for systems other than the BCS and the effluent pond (MCF_S) must be obtained from table A.5 using the appropriate system type and average annual temperature ($^{\circ}C$).
- (w) The fraction of volatile solids sent to systems other than the BCS and effluent pond ($MS_{L,S}$) for each livestock category represents the fraction of manure that was sent to (managed by) these systems, taking into account any volatile solids removed by solid separation equipment. Site-specific data must be used if available. If site-specific data is unavailable, values from table A.9 must be used to calculate $MS_{L,S}$.

Equation 5.9: Project Methane Emissions from *Non*-BCS Related Sources

$$PE_{CH_4,nBCS} = \left(\sum_L (EF_{CH_4,L,nBCSs} \times P_L) \right) \times 0.001$$

Where,

$PE_{CH_4, nBCS}$	=	Methane from sources in the waste treatment and storage category other than the BCS and associated effluent pond	<u>Units</u> mtCH ₄
$EF_{CH_4,L,nBCSs}$	=	Emission factor for the livestock population from non-BCS-related sources (nBCSs, calculated below)	kgCH ₄ / head/ yr
P_L	=	Average population of livestock category 'L' (based on monthly population data) for a given reporting period	
0.001	=	Conversion factor from kg to mt	

$$EF_{CH_4,L,nBCS} = (VS_L \times B_{o,L} \times RD_{rp} \times 0.68) \times \left(\sum_S (MCF_S \times MS_{L,S}) \right)$$

<i>Where,</i>		<u>Units</u>
$EF_{CH_4,L,nBCS}$	= Methane emission factor for the livestock population from non-BCS related sources	kgCH ₄ / head/ yr
VS_L	= Volatile solids produced by livestock category 'L' on a dry matter basis.	kg/ animal/ day
$B_{o,L}$	= Maximum methane producing capacity for manure for livestock category 'L' (of VS dry matter) from table A.2	m ³ CH ₄ /kg
RD_{rp}	= reporting days in a reporting period	days/yr
0.68	= Density of methane (1 atm, 60°F)	kg/m ³
MCF_S	= Methane conversion factor for system component 'S' from table A.4	fraction (0-1)
$MS_{L,S}$	= Percent of manure from livestock category L that is managed in non-BCS system component 'S'	fraction (0-1)

And:

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

<i>Where,</i>		<u>Units</u>
VS_L	= Volatile solid excretion on a dry matter weight basis	kg/ animal/ day
VS_{Table}	= Volatile solid excretion from tables A.2 and A.4	kg/ day/ 1000kg
$Mass_L$	= Average live weight for livestock category 'L',	kg

And:

$$P_L = \frac{\sum_i (RD_{rm,i} \times P_{L,i})}{RD_{rp}}$$

<i>Where,</i>		<u>Units</u>
$RD_{rm,i}$	= Reporting days in the reporting month	days
$P_{L,i}$	= Monthly average population of livestock category 'L'	
RD_{rp}	= Reporting days in the reporting period	days

5.3. Metered Methane Destruction Comparison

Offset projects must compare the modeled methane emission reductions for the reporting period, as calculated in equation 5.2 above, with the actual metered amount of methane that is destroyed by 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.

- (a) The total metered methane destruction (CH₄ destroyed) must be quantified using equation 5.10.
- (b) The quarterly methane concentration (C_{CH₄}) is used for the entire month in which it is taken and for all subsequent months until a new methane concentration is taken. A weighted average of more frequent samples may also be used.

- (c) All volume flows (F) must come from the monitored project-specific flow data corrected to standard conditions.
- (d) A site-specific biogas destruction efficiency (BDE_j) of each device must be used when available, and when the destruction device is not listed in table A.6. If a site-specific methane destruction efficiency for devices listed in table A.6 is not available then the default value from table A.6 must be used. Site-specific methane destruction efficiencies require prior written approval from the Executive Officer and must be equally or more accurate than the default destruction efficiencies.
- (e) Biogas flow to an inoperable device must be counted as a separate device with a biogas destruction efficiency (BDE_j) of zero when calculating the fractional monthly weighted average destruction efficiency of devices used during the month (BDE_{i,weighted}).

Equation 5.10 : Metered Methane Destruction

$$CH_{4,destroyed} = \sum_i (CH_{4meter,i} \times BDE_{i,weighted}) \times GWP_{CH4}$$

<i>Where,</i>		<u>Units</u>
CH _{4,destroyed}	= Aggregated quantity of methane collected and destroyed during the reporting period	mtCO ₂ e
CH _{4 meter,i}	= Monthly quantity of methane collected and metered.	mtCH ₄ / month
BDE _{i,weighted}	= Monthly weighted average of all destruction devices used in month <i>i</i>	fraction (0- 1)
GWP _{CH4}	= Global warming potential of methane	

With:

$$CH_{4 meter,i} = F_i \times C_{CH4} \times 0.0423 \times 0.000454$$

<i>Where,</i>		<u>Units</u>
C _{CH4}	= Quarterly methane concentration	fraction (0- 1)
F _i	= Volume of biogas from the digester in month <i>i</i>	scf

And:

$$BDE_{i,weighted} = \frac{\sum_j (F_{j,i} \times BDE_j)}{\sum_j F_{Fj,i}}$$

<i>Where:</i>		<u>Units</u>
j	= Destruction devices	
F _{j,i}	= Volume of biogas in month <i>i</i> sent to destruction device <i>j</i>	scf
BDE _j	= Biogas destruction efficiency of device <i>j</i>	Fraction (0- 1)

- (f) If gas flow metering equipment does not internally correct gas flow volumes to standard conditions, the Offset Project Operator or, if applicable, the Authorized Project Designee must apply equation 5.11 to the volume of biogas prior to calculating metered methane destruction in equation 5.10.

Equation 5.11: Biogas Volume corrected for Temperature and Pressure

$$F_{corrected,y} = F_{meas,y} \times \frac{519.67}{T_{meas,y}} \times \frac{P_{meas,y}}{1.00}$$

Where:

		<u>Units</u>
$F_{corrected,y}$	= Corrected volume of biogas for time interval y, adjusted to 60 °F and 1 atm	scf
$F_{meas,y}$	= Measured volume of biogas for time interval y	cf
$T_{meas,y}$	= Measured temperature of the biogas for time interval y, °R=°F+459.67	°R
$P_{meas,y}$	= Measured pressure of the biogas for the time interval y	atm

5.4. Quantifying Project Baseline and Project Carbon Dioxide Emissions

- (a) Carbon dioxide emissions associated with the project baseline or project activities include, but are not limited to, the following sources:
- (1) Electricity use by pumps and equipment;
 - (2) Fossil fuel generators used to destroy biogas;
 - (3) Power pumping systems;
 - (4) Milking parlor equipment;
 - (5) Flares;
 - (6) Tractors that operate in barns or freestalls;
 - (7) On-site manure hauling trucks; and
 - (8) Vehicles that transport manure off-site.
- (b) If it is demonstrated during verification that project carbon dioxide emissions are to be equal to or less than 5% of the total project baseline emissions of methane, project baseline and project carbon dioxide emissions may be estimated.
- (c) Baseline carbon dioxide emissions (BE_{CO_2}) must be calculated using equation 5.12.
- (d) The baseline quantities of electricity ($BE_{QE,c}$) and fossil fuel ($BE_{QF,c}$) consumed by each source must be taken from operational records such as utility bills and

delivery invoices unless the Offset Project Operator or Authorized Project Designee is allowed to estimate baseline carbon dioxide emissions pursuant to subchapter 5.4(b) of this protocol.

- (e) If the total electricity being generated by project activities is greater than or equal to the additional electricity consumption by the project ($PE_{QE,c} - BE_{QE,c}$) the baseline ($BE_{QE,c}$) and project ($PE_{QE,c}$) electricity consumption will both be set to zero.

Equation 5.12 Baseline Carbon Dioxide Emissions

$$BE_{CO2} = \sum_c (BE_{QE,c} \times EF_{CO2,e}) + \sum_c (BE_{QF,c} \times EF_{CO2,f}) \times 0.001$$

<i>Where,</i>		<u>Units</u>
BE_{CO2}	= Baseline anthropogenic carbon dioxide emissions from electricity consumption and mobile and stationary combustion sources	mtCO2e
$BE_{QE,c}$	= Baseline quantity of electricity consumed for each emissions source 'c'	MWh
$EF_{CO2,e}$	= CO ₂ emission factor e for electricity used; see appendix A for emission factors by eGRID subregion	mtCO2/MWh
$EF_{CO2,f}$	= Fuel-specific emission factor f from appendix A	kg CO2/MMBtu or kg CO2/gal
$BE_{QF,c}$	= Baseline quantity of fuel consumed for each mobile and stationary emission source 'c'	MMBtu or gal
0.001	= Conversion factor from kg to mt	

- (f) Project carbon dioxide emissions (PE_{CO2}) must be calculated using equation 5.13.
- (g) The project quantities of electricity ($PE_{QE,c}$) and fossil fuel ($PE_{QF,c}$) consumed by each source must be taken from operational records such as utility bills and delivery invoices unless the Offset Project Operator or Authorized Project Designee is allowed to estimate project carbon dioxide emissions pursuant to subchapter 5.4(b) of this protocol.

Equation 5.13 Project Carbon Dioxide Emissions

$$PE_{CO2} = \sum_c (PE_{QE,c} \times EF_{CO2,e}) + \sum_c (PE_{QF,c} \times EF_{CO2,f}) \times 0.001$$

<i>Where,</i>		<u>Units</u>
PE_{CO2}	= Project anthropogenic carbon dioxide emissions from electricity consumption and mobile and stationary combustion sources	mtCO2e
$PE_{QE,c}$	= Project quantity of electricity consumed for each emissions source 'c'	MWh

$EF_{CO_2,e}$	=	CO ₂ emission factor <i>e</i> for electricity used; see appendix A for emission factors by eGRID sub region	mtCO ₂ /MWh
$EF_{CO_2,f}$	=	Fuel-specific emission factor <i>f</i> from appendix A	kg CO ₂ /MM Btu or kg CO ₂ /gal
$PE_{QF,c}$	=	Project quantity of fuel consumed for each mobile and stationary emission source 'c'	MMBtu or gal
0.001	=	Conversion factor from kg to mt	

Chapter 6. Monitoring

6.1. General Monitoring Requirement - Quantification Methodology

- (a) The Offset Project Operator or Authorized Project Designee 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.
- (b) The Offset Project Operator or, if applicable, the Authorized Project Designee must monitor the methane capture and control system 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 total flow of biogas can come from one meter or summed from multiple meters;
 - (3) The flow of biogas delivered to each destruction device, measured continuously and recorded every 15 minutes or totalized and recorded at least daily, adjusted for temperature and pressure. A single meter may be used for multiple destruction devices. In this instance, methane destruction in these devices is eligible only if the operational activity of all these devices are independently monitored and the least efficient BDE of all destruction devices is used; and
 - (4) The fraction of methane in the biogas must be measured with a continuous analyzer or, alternatively, with quarterly measurements.
- (c) Flow data must be corrected for temperature and pressure at 60°F and 1 atm, either internally or by following equation 5.6.

- (d) The Offset Project Operator or, if applicable, the Authorized Project Designee must independently monitor the operational activity of each destruction device and must collect and maintain documentation at least hourly to ensure actual methane destruction. No registry offset credits or ARB offset credits will be issued for any time period during which the destruction device is not operational.
 - (1) Any destruction device equipped with a safety shut off device that prevents biogas flow to the destruction device when the destruction device is not operational does not require hourly monitoring, provided that the presence, operability, and use of the safety device are verified.
- (e) If for any reason the destruction device or the operational monitoring equipment is inoperable, during the period of inoperability, the destruction efficiency of the device is zero.
- (f) Data substitution is allowed for limited circumstances where a project encounters biogas flow rate or methane concentration data gaps. The Offset Project Operator or, if applicable, Authorized Project Designee must apply the data substitution methodology provided in appendix B. No data substitution is permissible for data gaps resulting from inoperable equipment that monitors the proper functioning of destruction devices, and no emission reductions will be credited under such circumstances.
- (g) Data substitution is required for all circumstances where a projects encounters project flow rate or methane concentration gaps. The Offset Project Operator or, if applicable, Authorized Project Designee must apply the data substitution methodology provided in appendix B. No data substitution is permissible for data gaps resulting from inoperable equipment that monitors the proper functioning of destruction devices and no emission reductions will be credited under such circumstances.

6.2. Biogas Measurement Instrument QA/QC – Quantification Methodology

- (a) All gas flow meters and continuous methane analyzers must be:
 - (1) Cleaned and inspected on a quarterly basis, with the activities performed and “as found/as left condition” of the equipment documented;

- (2) Field checked by a trained professional for calibration accuracy with the percent drift documented, using either a portable instrument (such as a pitot tube), a permanent fixture or manufacturer specifications, at the end of but no more than two months prior to the end date of the reporting period; and
 - (3) Calibrated by the manufacturer or a certified calibration service per manufacturer's specifications or every 5 years, whichever is more frequent.
- (b) If the field check on a piece of equipment after cleaning reveals accuracy outside of a +/- 5% threshold, the equipment must be calibrated by the manufacturer or a certified service provider. The Offset Project Operator or, if applicable, Authorized Project Designee must maintain documentation of efforts to calibrate the equipment within 30 days of the failed field check or a biogas destruction efficiency of zero must be assigned to all destruction devices monitored by the equipment from date of discovery until calibration.
- (c) For the interval between the last successful field check and any calibration event confirming accuracy outside 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 the flow meter was outside the +/- 5% accuracy threshold, the project developer must estimate total emission reductions independently for each meter using:
 - (A) The metered values without correction; and
 - (B) The metered values adjusted based on the greatest calibration drift recorded at the time of calibration.
 - (2) The lower of the two emission reduction estimates must be reported as the scaled emission reduction estimate.
- (d) If a portable instrument is used (such as a handheld methane analyzer), the portable instrument must be calibrated per manufacturer's specifications or at least once during each reporting period, whichever is more frequent, by the manufacturer or at an ISO 17025 certified laboratory.

6.3. Document Retention

- (a) The Offset Project Operator or Authorized Project Designee is required to keep all documentation and information outlined in the Regulation and this protocol. Record retention requirements are set forth in section 95976 of the Regulation.
- (b) Information that must be retained by the Offset Project Operator or Authorized Project Designee must include, but is not limited to:
 - (1) All data inputs for the calculation of the project baseline emissions and project emission reductions;
 - (2) Emission reduction calculations;
 - (3) Relevant sections of the BCS operating permits;
 - (4) BCS information (installation dates, equipment list, etc.);
 - (5) Biogas flow meter information (model number, serial number, manufacturer's calibration procedures) ;
 - (6) Cleaning and inspection records for all biogas meters;
 - (7) Field check results for all biogas meters;
 - (8) Calibration results for all biogas meters;
 - (9) Methane monitor information (model number, serial number, calibration procedures);
 - (10) Biogas flow data (for each flow meter);
 - (11) Biogas temperature and pressure readings (only if flow meter does not correct for temperature and pressure automatically);
 - (12) Methane concentration monitoring data;
 - (13) Destruction device monitoring data (for each destruction device);
 - (14) Destruction device, methane monitor and biogas flow monitor information (model numbers, serial numbers, calibration procedures); and
 - (15) All maintenance records relevant to the BCS, monitoring equipment, and destruction devices.
- (c) If using a calibrated portable gas analyzer for CH₄ content measurement, all of the following information must also be included:
 - (1) Date, time, and location of methane measurement;
 - (2) Methane content of biogas (% by volume) for each measurement ;
 - (3) Methane measurement instrument type and serial number;

- (4) Date, time, and results of instrument calibration; and
 - (5) Corrective measures taken if instrument does not meet performance specifications.
- (d) See the Regulation for additional record-keeping requirements.

6.4. Monitoring Parameters – Quantification Methodology

Provisions for monitoring other variables to calculate project baseline and project emissions are provided in table 6.1.

Table 6.1. Project Monitoring Parameters

Eq. #	Parameter	Description	Data unit	calculated (c) measured (m) reference(r) operating records (o)	Measurement frequency	Comment
General Project Parameters						
5.1 5.6 5.10	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 'C _{CH₄} ' parameters below). Verifier: Review meter reading data; Confirm proper operation and maintenance in accordance with the manufacturer's specifications; Confirm meter calibration data.
5.2 5.3	L	Type of livestock categories on the farm	Livestock categories	o	Monthly	Select from list provided in table A.1. Verifier: Review herd management software; Conduct site visit; Interview operator.
5.3	VS _{deg}	Monthly volatile solids degraded 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.
5.3 5.4 5.8 5.9	B _{0,L}	Maximum methane producing capacity for manure by livestock category	(m ³ CH ₄ /kgVS)	r	Once per reporting period	From table A.2. Verifier: Verify correct value from table used.
5.3	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.
5.3 5.4 5.8 5.9	VS _L	Daily volatile solid production	(kg/animal/day)	r, c	Once per reporting period	From table A.2 and table A.4; Verifier: Ensure appropriate year's table is used; Review data units.

5.3	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.
5.3 5.4 5.8 5.9	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).
5.3 5.4 5.8 5.9	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 (table A.1). Verifier: Conduct site visit; Interview livestock operator; Review average daily gain records, operating records.
5.3	T ₂	Average monthly temperature at location of the operation	oC	m/o	Monthly	Used for van't Hoff-Arrhenius factor calculation and for choosing appropriate MCF value. Verifier: Review temperature records obtained from weather service.
5.6	CH ₄ meter, _i	Quantity of methane collected and metered in month _i	mtCH ₄ /Month	m/o	Monthly	Used for calculating PE _{CH₄} , BCS.
5.6	BCE	Biogas capture efficiency of the anaerobic digester, accounts for gas leaks.	Fraction (0-1)	r	Once per reporting period	Use default value from table A.3. Verifier: Review operation and maintenance records to ensure proper functionality of BCS.

5.6 5.10	BDE	Methane destruction efficiency of destruction device(s)	Fraction (0-1)	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.
5.6	C _{CH4}	Methane concentration of biogas	Fraction (0-1)	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.
5.6 5.7 5.10 5.11	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.
5.6	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.
5.6	t	The number of days of the month that biogas is venting uncontrolled from the project's BCS.	Days	m, o	Monthly	

5.6	MS_{BCS}	The maximum biogas storage of the BCS system	scf	r	Once per reporting period	Obtained from digester system design plans. Necessary to quantify the release of methane to the atmosphere due to an uncontrolled venting event.
5.7 5.11	T	Temperature of the biogas	$^{\circ}R$ (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.
5.8	VS_{ep}	Average daily volatile solid of digester effluent to effluent pond	kg/day	c	Once per reporting period	If project uses effluent pond, equals 30% of the average daily VS entering the digester. Verifier: Review VSep calculations.
5.8	MCF_{ep}	Methane conversion factor for BCS effluent pond	Fraction (0-1)	r	Once per reporting period	Referenced from appendix A. The Offset Project Operator or Authorized Project Designee must use the liquid slurry MCF value. Verifier: Verify value from table.
5.8	$MS_{L,BCS}$	Fraction of manure from each livestock category managed in the BCS	Fraction (0-1)	o	Once per reporting period	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.
5.9	$EF_{CH_4,L}$ (nBCSs)	Methane emission factor for the livestock population from non-BCS-related sources	(kgCH ₄ /head/year)	c	Once per reporting period	Emission factor for all non-BCS storage systems, differentiated by livestock category. Verifier: Review calculation, operation records.
5.9	MCF_s	Methane conversion factor for manure management system component 'S'	Fraction (0-1)	r	Once per reporting period	From appendix A. Differentiate by livestock category. Verifier: Verify correct value from table used.

5.9	MS _L	Fraction of manure from each livestock category managed in the baseline waste handling system 'S'	Fraction (0-1)	o	Once per reporting period	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%. Verifier: Conduct site visit; Interview operator; Review baseline scenario documentation.
5.9	MS _{L,S}	Fraction of manure from each livestock category managed in non-anaerobic manure management system component 'S'	Fraction (0-1)	o	Monthly	Based on configuration of manure management system, differentiated by livestock category. Verifier: Conduct site visit; Interview operator.
5.10	CH _{4,destroyed}	Aggregated amount of methane collected and destroyed in the BCS	Metric tons of CH ₄	c, m	Once per reporting period	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.
5.12	BE _{QEc}	Baseline quantity of electricity consumed	MWh/year	o, c	Once per reporting period	Electricity used by project for manure collection, transport, treatment/storage, and disposal. Verifier: Review operating records and quantity calculation.
5.12 5.13	EF _{CO_{2,e}}	Emission factor for electricity used by project	tCO ₂ /MWh	r	Once per reporting period	Refer to appendix A for emission factors. If biogas produced from digester is used to generate electricity consumed, the emission factor is zero. Verifier: Review emission factors.

5.12 5.13	EF _{CO2,f}	Fuel-specific emission factor for mobile and stationary combustion sources	kg CO2/MMBTU or kg CO2/gallon	r	Once per reporting period	Refer to appendix A for emission factors. If biogas produced from digester is used as an energy source, the emission factor is zero. Verifier: Review emission factors.
5.12	BE _{QFc}	Baseline quantity of fuel used for mobile/stationary combustion sources	MMBTU/ye ar or gallon/year	o, c	Once per reporting period	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.
5.13	PE _{QEc}	Project quantity of electricity consumed	MWh/year	o, c	Once per reporting period	Electricity used by project for manure collection, transport, treatment/storage, and disposal. Verifier: Review operating records and quantity calculation.
5.13	PE _{QFc}	Project quantity of fuel used for mobile/stationary combustion sources	MMBTU/ye ar or gallon/year	o, c	Once per reporting period	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.

Chapter 7. Reporting

General requirements for reporting and record retention are included in the Regulation. In addition to the offset project requirements in sections 95975 and 95976 the Regulation, livestock offset projects must follow the project listing and reporting requirements below.

7.1. Listing Requirements

- (a) Listing information must be submitted by the Offset Project Operator or Authorized Project Designee no later than the date on which the Offset Project Operator or Authorized Project Designee submits the first Offset Project Data Report.
- (b) In order for a livestock Compliance Offset Project to be listed, the Offset Project Operator or Authorized Project Designee must submit the information required by section 95975 of the Regulation, in addition to all the following information:
 - (1) Offset project name and ID number(s);
 - (2) Name and CITSS ID number for the:
 - (A) Offset Project Operator; and,
 - (B) Authorized Project Designee (if applicable);
 - (3) Contact information for both the Offset Project Operator and, if applicable, the Authorized Project Designee, including all of the following information:
 - (A) Entity's mailing address;
 - (B) Contact person's name;
 - (C) Contact person's phone number; and
 - (D) Contact person's email address;
 - (4) Contact information, including name, phone number, email address, and, if applicable, the organizational affiliation for:
 - (E) The person submitting the listing information;
 - (F) Technical consultants; and
 - (G) Other parties with a material interest;
 - (5) Name of facility owner;
 - (6) Date of form completion;
 - (7) Offset project description: 1-2 paragraphs (including type of digester and method of destruction);
 - (8) Offset project site address (including all governing jurisdictions and latitude/longitude);

- (9) Name and address of animal facility (if different from project site);
- (10) Description of type of facility (e.g., dairy, swine, or combined);
- (11) Offset project commencement date;
- (12) Initial reporting period start and end dates;
- (13) Indication whether any GHG reductions associated with the offset project have ever been registered with or claimed by another registry or program, or sold to a third party prior to our listing; if so, identification of the registry or program, as well as vintage and reporting period; and
- (14) Indication whether the offset project is being implemented and conducted as the result of any law, statute, regulation, court order, or other legally binding mandate. If so, an explanation must also be provided;

7.2. Offset Project Data Report

- (a) The Offset Project Operator or, if applicable, Authorized Project Designee must submit an Offset Project Data Report at the conclusion of each Reporting Period according to the reporting schedule in section 95976 of the Regulation.
- (b) The Offset Project Operator or, if applicable, Authorized Project Designee must submit the information required by section 95976 of the Regulation, in addition to all of the following information:
 - (1) Offset project name and ID number(s);
 - (2) Name and CITSS ID number for the:
 - (A) Offset Project Operator; and,
 - (B) Authorized Project Designee (if applicable);
 - (3)
 - (C) Contact information for both the Offset Project Operator and, if applicable, the Authorized Project Designee, including all of the following information: Entity's mailing address;
 - (D) Contact person's name;
 - (E) Contact person's phone number; and
 - (F) Contact person's email address;
 - (4) Contact information including name, phone number, email address, and, if applicable, the organization affiliation for the person submitting the reporting information;

- (5) Date OPDR completed;
- (6) Reporting period start and end dates;
- (7) Indication whether the offset project meets all local, state, or federal regulatory requirements;
- (8) Offset project commencement date;
- (9) Facility name and location;
- (10) Indication whether all the information in the offset project listing is still accurate. If not provide updates;
- (11) Project baseline emissions;
- (12) Project emissions; and
- (13) Total GHG emission reductions.

Chapter 8. Verification

- (a) All Offset Project Data Reports are subject to regulatory verification as required in section 95977 of the Regulation by an ARB accredited offset verification body.
- (b) The Offset Project Data Reports must receive a positive or qualified positive verification statement to be issued ARB or registry offset credits.

Appendix A Emissions Factor Tables – Quantification Methodology

Table A.1. Livestock Categories and Typical Average Mass (Mass_L)

Livestock Category (L)	Livestock Typical Average Mass (TAM) in kg
Dairy cows (on feed)	680
Non-milking dairy cows (on feed)	684
Heifers (on feed)	407
Bulls (grazing)	874
Calves (grazing)	118
Heifers (grazing)	351.5
Cows (grazing)	582.5
Nursery swine	12.5
Grow/finish swine	70
Breeding swine	198

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

Livestock category (L)	VS _{Table} (kg/day/1,000 kg mass)	B _{o,L} (m ³ CH ₄ /kg VS added)
Dairy cows	See table A.4	0.24
Non-milking dairy cows	5.56	0.24
Heifers	See table A.4	0.17
Bulls (grazing)	6.04	0.17
Calves (grazing)	7.70	0.17
Heifers (grazing)	See table A.4	0.17
Cows (grazing)	See table A.4	0.17
Nursery swine	8.89	0.48
Grow/finish swine	5.36	0.48
Breeding swine	2.71	0.35

Table A.3. Biogas Collection Efficiency by Digester Type

Digester Type	Cover Type	Biogas Collection Efficiency (BCE)
Covered Anaerobic Lagoon	Bank-to-Bank, impermeable	0.95
	Partial area (modular), impermeable	0.95 x % area covered
Complete mix, plug flow, or fixed film digester	Enclosed vessel	0.98

Table A.4. 2012 Volatile Solid (VS_{table}). 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	8.62	8.44	19.67	7.82
Alaska	8.71	8.44	30.94	8.89
Arizona	11.64	8.44	22.32	8.89
Arkansas	8.44	8.44	18.38	7.82
California	11.41	8.44	13.96	8.89
Colorado	11.64	8.44	12.28	8.89
Connecticut	10.41	8.44	23.35	7.87
Delaware	10.18	8.44	16.82	7.87
Florida	10.36	8.44	21.99	7.82
Georgia	10.40	8.44	19.17	7.82
Hawaii	8.70	8.44	20.25	8.89
Idaho	11.45	8.44	13.75	8.89
Illinois	10.30	8.44	11.42	7.47
Indiana	10.85	8.44	11.72	7.47
Iowa	10.96	8.44	9.54	7.47
Kansas	10.94	8.44	8.99	7.47
Kentucky	9.20	8.44	14.69	7.82
Louisiana	8.41	8.44	21.36	7.82
Maine	10.01	8.44	15.12	7.87
Maryland	10.20	8.44	17.18	7.87
Massachusetts	9.91	8.44	20.89	7.87
Michigan	11.56	8.44	12.19	7.47
Minnesota	10.29	8.44	11.47	7.47
Mississippi	8.96	8.44	19.31	7.82
Missouri	8.92	8.44	14.84	7.47
Montana	10.85	8.44	18.50	7.82
Nebraska	10.79	8.44	11.97	8.89
Nevada	11.33	8.44	14.77	7.47
New Hampshire	10.34	8.44	23.83	8.92
New Jersey	10.01	8.44	16.56	7.87
New Mexico	11.85	8.44	14.27	7.87
New York	10.93	8.44	16.72	8.89
North Carolina	10.79	8.44	19.93	7.87
North Dakota	10.22	8.44	14.61	7.82
Ohio	10.39	8.44	13.24	7.47
Oklahoma	9.76	8.44	12.67	7.47
Oregon	10.57	8.44	15.75	7.82

Pennsylvania	10.32	8.44	16.19	8.89
Rhode Island	9.93	8.44	20.89	7.87
South Carolina	9.85	8.44	19.71	7.87
South Dakota	10.86	8.44	12.77	7.82
Tennessee	9.49	8.44	16.25	7.47
Texas	11.06	8.44	11.15	7.82
Utah	10.95	8.44	16.65	7.82
Vermont	10.23	8.44	16.08	8.89
Virginia	10.06	8.44	17.93	7.87
Washington	11.58	8.44	12.06	7.82
West Virginia	9.18	8.44	19.13	8.89
Wisconsin	10.87	8.44	17.03	7.47
Wyoming	10.69	8.44	18.18	8.89

Table A.5. IPCC 2006 Methane Conversion Factors by Manure Management System Component/Methane Source 'S'

MCF VALUES BY TEMPERATURE FOR MANURE MANAGEMENT SYSTEMS																					
System		MCFs by average reporting period 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		0.01					0.02										0.02				Judgment of IPCC Expert Group in combination with Hashimoto and Steed (1994).
Daily spread		0.001					0.02										0.01				Hashimoto and Steed (1993).
Solid storage		0.02					0.04										0.05				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		0.01					0.02										0.02				Judgment of IPCC Expert Group in combination with Hashimoto and Steed (1994).
Liquid / Slurry	With natural crust cover	0.10	0.11	0.13	0.14	0.15	0.17	0.18	0.20	0.22	0.24	0.26	0.29	0.31	0.34	0.37	0.41	0.44	0.48	0.50	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

Table A.5. Continued

MCF VALUES BY TEMPERATURE FOR MANURE MANAGEMENT SYSTEMS																				
System	MCFs by average reporting period 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	0.66	0.68	0.70	0.71	0.73	0.74	0.75	0.76	0.77	0.77	0.78	0.78	0.78	0.79	0.79	0.79	0.79	0.80	0.80	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	0.03					0.03										0.03			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	0.19	0.19	0.20	0.22	0.25	0.27	0.29	0.32	0.35	0.39	0.42	0.46	0.50	0.55	0.60	0.65	0.71	0.78	0.80

Table A.5. Continued

MCF VALUES BY TEMPERATURE FOR MANURE MANAGEMENT SYSTEMS																					
System		MCFs by average reporting period 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		0.0-1.00					0.0-1.00										0.0-1.00				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		0.10					0.10										0.10				Judgment of IPCC Expert Group in combination with Safley et al. (1992).
Cattle and Swine deep bedding	< 1 month	0.03					0.03										0.30				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	0.17	0.19	0.20	0.22	0.25	0.27	0.29	0.32	0.35	0.39	0.42	0.46	0.50	0.55	0.60	0.65	0.71	0.78	0.90	Judgment of IPCC Expert Group in combination with Mangino et al. (2001).
Composting - In-vessel ^a		0.005					0.005										0.005				Judgment of IPCC Expert Group and Amon et al. (1998). MCFs are less than half of solid storage. Not temperature dependant.
Composting - Static pile ^a		0.005					0.005										0.005				Judgment of IPCC Expert Group and Amon et al. (1998). MCFs are less than half of solid storage. Not temperature dependant.

Table A.5. Continued

Composting - Intensive windrow ^a	0.005	0.01	0.015	Judgment of IPCC Expert Group and Amon et al. (1998). MCFs are slightly less than solid storage. Less temperature dependant.
Composting – Passive windrow ^a	0.005	0.01	0.015	Judgment of IPCC Expert Group and Amon et al. (1998). MCFs are slightly less than solid storage. Less temperature dependant.
Aerobic treatment	0.00	0.00	0.00	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 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. Biogas Destruction Efficiency Default Values by Destruction Device

If available, the actual source test results for the measured methane destruction efficiency must be used in place of the default methane destruction efficiency. Otherwise, the Offset Project Operator or Authorized Project Designee must use the default methane destruction efficiencies provided below.

Biogas Destruction Device	Biogas Destruction Efficiency (BDE)
Open Flare	0.96
Enclosed Flare	0.995
Lean-burn Internal Combustion Engine	0.936
Rich-burn Internal Combustion Engine	0.995
Boiler	0.98
Microturbine or large gas turbine	0.995
Upgrade and use of gas as CNG/LNG fuel	0.95
Upgrade and injection into natural gas transmission and distribution pipeline	0.98
Direct pipeline to an end-user	Per corresponding destruction device

Table A.7. CO₂ Emission Factors for Fossil Fuel Use

Fuel Type	Default High Heat Value	Default CO ₂ Emission Factor	Default CO ₂ Emission Factor
Coal and Coke	MMBtu / short ton	kg CO ₂ / MMBtu	kg CO ₂ / short ton
Anthracite	25.09	103.54	2597.819
Bituminous	24.93	93.40	2328.462
Subbituminous	17.25	97.02	1673.595
Lignite	14.21	96.36	1369.276
Coke	24.80	102.04	2530.592
Mixed (Commercial sector)	21.39	95.26	2037.611
Mixed (Industrial coking)	26.28	93.65	2461.122
Mixed (Electric Power sector)	19.73	94.38	1862.117
Natural Gas	MMBtu / scf	kg CO ₂ / MMBtu	kg CO ₂ / scf
(Weighted U.S. Average)	1.028 x 10 ⁻³	53.02	0.055
Petroleum Products	MMBtu / gallon	kg CO ₂ / MMBtu	kg CO ₂ / gallon
Distillate Fuel Oil No. 1	0.139	73.25	10.182
Distillate Fuel Oil No. 2	0.138	73.96	10.206
Distillate Fuel Oil No. 4	0.146	75.04	10.956
Distillate Fuel Oil No. 5	0.140	72.93	10.210
Residual Fuel Oil No. 6	0.150	75.10	11.265
Used Oil	0.135	74.00	9.990
Kerosene	0.135	75.20	10.152
Liquefied petroleum gases (LPG)	0.092	62.98	5.794
Propane	0.091	61.46	5.593
Propylene	0.091	65.95	6.001
Ethane	0.069	62.64	4.322
Ethanol	0.084	68.44	5.749
Ethylene	0.100	67.43	6.743
Isobutane	0.097	64.91	6.296
Isobutylene	0.103	67.74	6.977
Butane	0.101	65.15	6.580
Butylene	0.103	67.73	6.976
Naphtha (<401 deg F)	0.125	68.02	8.503
Natural Gasoline	0.110	66.83	7.351
Other Oil (>401 deg F)	0.139	76.22	10.595
Pentanes Plus	0.110	70.02	7.702
Petrochemical Feedstocks	0.129	70.97	9.155
Petroleum Coke	0.143	102.41	14.645
Special Naphtha	0.125	72.34	9.043
Unfinished Oils	0.139	74.49	10.354
Heavy Gas Oils	0.148	74.92	11.088

Lubricants	0.144	74.27	10.695
Motor Gasoline	0.125	70.22	8.778
Aviation Gasoline	0.120	69.25	8.310
Kerosene-Type Jet Fuel	0.135	72.22	9.750
Asphalt and Road Oil	0.158	75.36	11.907
Crude Oil	0.138	74.49	10.280
Other fuels (solid)	MMBtu / short ton	kg CO₂ / MMBtu	kg CO₂ / short ton
Municipal Solid Waste	9.95	90.7	902.465
Tires	26.87	85.97	2310.014
Plastics	38.00	75.00	2850.000
Petroleum Coke	30.00	102.41	3072.300
Other fuels (gaseous)	MMBtu / scf	kg CO₂ / MMBtu	kg CO₂ / scf
Blast Furnace Gas	0.092×10^{-3}	274.32	0.025
Coke Oven Gas	0.599×10^{-3}	46.85	0.028
Propane Gas	2.516×10^{-3}	61.46	0.155
Fuel Gas	1.388×10^{-3}	59.00	0.082
Biomass Fuels (solid)	MMBtu / short ton	kg CO₂ / MMBtu	kg CO₂ / short ton
Wood and Wood Residuals	15.38	93.80	1442.644
Agricultural Byproducts	8.25	118.17	974.903
Peat	8.00	111.84	894.720
Solid Byproducts	25.83	105.51	2725.323
Biomass Fuels (gaseous)	MMBtu / scf	kg CO₂ / MMBtu	kg CO₂ / scf
Biogas (Captured methane)	0.841×10^{-3}	52.07	0.044
Biomass Fuels (liquid)	MMBtu / gallon	kg CO₂ / MMBtu	kg CO₂ / gallon
Ethanol	0.084	68.44	5.749
Biodiesel	0.128	73.84	9.452
Rendered Animal Fat	0.125	71.06	8.883
Vegetable Oil	0.120	81.55	9.786

Table A.8. CO2 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	1,256.87	0.570
AKMS	ASCC Miscellaneous	448.57	0.203
AZNM	WECC Southwest	1,177.61	0.534
CAMX	WECC California	610.82	0.277
ERCT	ERCOT All	1,218.17	0.553
FRCC	FRCC All	1,196.71	0.543
HIMS	HICC Miscellaneous	1,330.16	0.603
HIOA	HICC Oahu	1,621.86	0.736
MROE	MRO East	1,610.80	0.731
MROW	MRO West	1,536.36	0.697
NEWE	NPCC New England	722.07	0.328
NWPP	WECC Northwest	842.58	0.382
NYCW	NPCC NYC/Westchester	622.42	0.282
NYLI	NPCC Long Island	1,336.11	0.606
NYUP	NPCC Upstate NY	545.79	0.248
RFCE	RFC East	1,001.72	0.454
RFCM	RFC Michigan	1,629.38	0.739
RFCW	RFC West	1,503.47	0.682
RMPA	WECC Rockies	1,896.74	0.860
SPNO	SPP North	1,799.45	0.816
SPSO	SPP South	1,580.60	0.717
SRMV	SERC Mississippi Valley	1,029.82	0.467
SRMW	SERC Midwest	1,810.83	0.821
SRSO	SERC South	1,354.09	0.614
SRTV	SERC Tennessee Valley	1,389.20	0.630
SRVC	SERC Virginia/Carolina	1,073.65	0.487

Table A.9. Volatile Solids Removed Through Solids Separation

Type of Solids Separation	Volatile Solids Removed (fraction)
Gravity	0.45
Mechanical:	
Stationary screen	0.17
Vibrating screen	0.15
Screw press	0.25
Centrifuge	0.50
Roller drum	0.25
Belt press/screen	0.50

Table A.10. Baseline Assumptions for Greenfield Projects

Baseline Assumption	Dairy Cattle Operations		Swine Operations
	>200 Mature Dairy Cows	<200 Mature Dairy Cows	
Anaerobic manure storage system	Flush system into an anaerobic lagoon with >30 day retention time	Flush system into an anaerobic lagoon with >30 day retention time	Flush system into an anaerobic lagoon with >30 day retention time
Non-anaerobic manure storage system(s)	Solids storage	Solids Storage	Solids Storage
MS_L	90% lagoon 10% solids storage	50% lagoon 50% solids storage	95% lagoon 5% solids storage
Lagoon cleaning schedule	Annually, in September	Annually, in September	Annually, in September

Appendix B Data Substitution – Quantification Methodology

The methodology presented below may be used only for missing or non-quality assured methane concentration parameters or for missing or non-quality assured flow metering parameters.

- (a) The data substitution methodology in table B.1 is allowed for limited circumstances where a project encounters flow rate or methane concentration data gaps that are discrete, limited, non-chronic, and due to unforeseen circumstances.
 - (1) Data substitution can only be applied to methane concentration *or* flow readings, but not both simultaneously, except as noted in table B.1.
 - (2) Substitution may only occur when two other monitored parameters corroborate and document proper functioning of the destruction device and system operation within normal ranges, except as noted in table B.1.
 - (A) Proper functioning of the destruction device can be documented by thermocouple readings for flares or engines, energy output for engines, etc.
 - (B) For methane concentration substitution, flow rates during the data gap must be consistent with normal operation.
 - (C) For flow rate substitution, methane concentrations during the data gap must be consistent with normal operations.
 - (D) If corroborating parameters fail to meet any of these requirements, no substitution may be employed.
- (b) The data substitution methodology in table B.1 is required for all circumstances where a projects encounters project flow rate or methane concentration gaps.
- (c) Data substitution is not permissible for equipment that monitors operation of destruction devices and a BDE of 0% must be used for all periods where the operation of the destruction device is not assured.

Table B.1. Missing Data

Duration of Missing Data	Substitution Methodology
Less than six hours of one parameter	Use the average of the four hours immediately before and following the outage.
Six to 24 hours of one parameter	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 of one parameter	Use the 95% lower or upper confidence limit of the 72 hours prior to and after the outage, whichever results in greater conservativeness.
One quarter of methane concentration data	Use the highest or lowest value for the other three quarters of methane concentration data, whichever results in greater conservativeness. This may only be applied once per reporting period.
Greater than one week of one parameter or any time with more than one parameter	Take a zero BDE for the device(s) in question with missing data and use the 99% lower or upper confidence limit of all available valid data for the reporting period, whichever results in greater conservativeness. If less than 25% of the data for the reporting period is available, then the single highest or lowest data point must be used.