CLIMATE FORWARD

Dairy Digester Project Forecast Methodology

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A program of the CLIMATE ACTION RESERVE

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Abbreviations and Acronyms

BCS	Biogas control system
CEQA	California Environmental Quality Act
CO_2	Carbon dioxide
CH_4	Methane
EF	Emission factor
FMU	Forecasted Mitigation Unit
GHG	Greenhouse gas
t	Metric ton (or tonne)
N_2O	Nitrous oxide
Reserve	Climate Action Reserve
SSR	Source, sink, and reservoir

1 Introduction

The Climate Action Reserve (Reserve) is an environmental nonprofit organization that promotes and fosters the reduction of greenhouse gas (GHG) emissions through credible market-based policies and solutions. Based in Los Angeles, the Reserve is the foremost carbon offset registry in North America with internationally recognized expertise in project-level GHG accounting. The Reserve establishes regulatory-quality standards for the development and quantification of GHG emission reduction projects; issues GHG emission reduction credits for use in compliance and voluntary carbon programs; and tracks the transaction of credits over time in transparent, publicly-accessible systems. Adherence to the Reserve's standards ensures that emission reductions associated with projects are real, permanent, and additional, thereby instilling confidence in the environmental benefit, credibility, and efficiency of carbon markets.

Climate Forward, a greenhouse gas mitigation program of the Climate Action Reserve, provides a practical solution to companies and organizations seeking cost-effective mitigation of anticipated (i.e., future) operational and/or project-related GHG emissions. Climate Forward facilitates investments in GHG reduction[1] activities that are practical, scientifically-sound, transparent, and aligned with forward-looking mitigation needs such as the California Environmental Quality Act (CEQA). Climate Forward will drive forward-looking investment into actions expected to result in GHG reductions, with a goal of expanding the scope and scale of feasible emission reduction project types.

Climate Forward is designed to provide companies, organizations, developers, and other entities with a conservative, robust, and methodologically rigorous option to mitigate an estimate of expected GHG emissions, on a voluntary or compliance basis, using Forecasted Mitigation Units (FMUs) generated from mitigation projects under this program. Climate Forward fundamentally differs from existing carbon credit programs through its focus on projecting and crediting estimated emission reductions on an *ex ante* basis. Under Climate Forward, estimated GHG reductions from the mitigation project are recognized as FMUs, which are each equal to one metric ton of carbon dioxide equivalent (CO_2e) expected to be reduced or sequestered. FMUs can be retired for multiple purposes, including for CEQA mitigation or for other voluntary mitigation purposes.

The Dairy Digester Project Forecast Methodology provides guidance to forecast and report GHG emission reductions associated with the installation or expansion of a biogas control system (BCS) for manure management on dairy cattle farms.[2] This methodology focuses on quantifying the change in methane emissions, but also accounts for potential increases in carbon dioxide emissions. Project proponents that install manure biogas capture and destruction technologies use this document to register forecasted GHG reductions with Climate Forward. The methodology provides eligibility rules, methods to forecast and calculate reductions, and procedures for reporting project information to Climate Forward. Additionally, a Project Implementation Report will receive independent confirmation by a Reserve-approved confirmation body selected by the project proponent. Guidance for confirmation bodies to

[1] Throughout this document, the term "reduction" is intended to address both GHG emission reductions that are the result of activities designed to reduce or avoid emissions, and GHG removals, which are those activities aimed at removing atmospheric CO_2 at rates that exceed "business as usual" sequestration.
[2] The Dairy Digester Project Forecast Methodology is largely adapted from the Climate Action Reserve's U.S. Livestock Project Protocol Version 4.0 and includes much of the original language, pertinent appendices, and background material.

confirm reductions is provided in the Climate Forward Confirmation Manual and Section 8 of this methodology.

This methodology facilitates the creation of GHG emission reductions determined in a complete, consistent, transparent, accurate, and conservative manner while incorporating relevant sources.[3]

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

2 The GHG Reduction Project

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

2.1 Project Definition

For the purpose of this methodology, the GHG reduction project is defined as the installation, or expansion, and operation of a BCS[4] that captures and destroys methane gas from anaerobic manure treatment and/or storage facilities at dairy operations. The BCS must destroy methane gas that would otherwise have been emitted to the atmosphere in the absence of the project from uncontrolled anaerobic treatment and/or storage of manure.

Captured biogas must then be destroyed onsite (whether by flare or combustion for electricity generation), or transported for offsite use (e.g., through gas distribution or transmission pipeline), or used to power vehicles. Regardless of how project proponents utilize the captured biogas, the ultimate fate of the methane must be destruction.

“Centralized digesters” that integrate waste from more than one dairy operation do not meet the definition of a project under this methodology; however, a dairy operation that maintains offsite housing for support animal stock and transports manure regularly to the project BCS meets the project definition under this methodology, provided the housing is permitted and operated by the dairy operation comprising the BCS. Third-party facilities contracted to maintain support animal stock or facilities contracted to contribute manure to the project BCS do not meet this definition, although this methodology does not prohibit project proponents from co-digesting these manure waste sources.

Note that this methodology does not preclude project proponents from co-digesting organic matter in the BCS. However, the additional organics could impact the nutrient properties of digester effluent and project proponents should consider this when assessing the project’s associated water quality impacts.

2.2 The Project Proponent

The “project proponent” is an entity that has an active account on the Climate Forward registry, submits a project for listing and registration with Climate Forward, and is ultimately responsible for all project reporting and confirmation activities. In all cases, the project proponent must attest to the Reserve that they have exclusive claim to the GHG reductions resulting from the project. At the time a project is confirmed, the project proponent must attest that no other entities are reporting or claiming (e.g., for voluntary reporting or regulatory compliance purposes) the GHG reductions caused by the project (see Section 3.6).[5] The Reserve will not issue credits for GHG

[4] Biogas control systems encompass anaerobic digester systems – which may be designed and operated in a variety of ways (ambient temperature covered lagoons, heated lagoons, mesophilic plug flow or complete mix tank digesters) – as well as methane destruction systems, such as flares or engines.

[5] A standard form for this attestation is available on the Climate Forward website at https://climateforward.org/program/program-and-project-forms/.

reductions that are reported or claimed by entities other than the project proponent (e.g., implementation agents or others not designated as the project proponent). Under this methodology, the project proponent is the only required party to be involved with project implementation.

3 Eligibility Rules

Projects must fully satisfy the following eligibility rules in order to register with Climate Forward. The criteria only apply to projects that meet the definition of a GHG reduction project (Section 2.1).

Eligibility Rule I:	Location	⟶	United States, its territories and tribal lands
Eligibility Rule II:	Start Date	⟶	Start date is no more than one year prior to project submission
	Crediting Period	⟶	Crediting period may be up to 15 years
Eligibility Rule III:	Additionality	⟶	Meet performance standard: Installation of a BCS that captures and destroys methane gas from anaerobic manure treatment and/or storage facilities on dairy operations
		⟶	Demonstrate that project passes the legal requirement test
		⟶	Demonstrate anaerobic baseline conditions at existing dairy operations or common practice for greenfield projects
		⟶	Exceed regulatory requirements
Eligibility Rule IV:	Environmental and Social Safeguards	⟶	No negative environmental and social impacts
Eligibility Rule V:	Regulatory Compliance	⟶	Comply with all applicable laws
Eligibility Rule VI:	Ownership and Double Counting	⟶	Must not receive credits from more than one program, where GHG boundaries overlap
Eligibility Rule VII:	Project Resilience Measures	⟶	Project must address risks of failure to reach expectations

3.1 Location

Only projects located in the United States and its territories, or on U.S. tribal lands, are eligible to register FMUs with Climate Forward under this methodology.

3.2 Project Start Date and Crediting Period

The start date for a dairy digester project is defined as the date on which the project's BCS becomes operational. For the purpose of this methodology, a BCS is considered operational on the date that the system begins producing and destroying methane gas after completion of an initial start-up period. An initial start-up period must not exceed a nine-month period following the date on which the BCS first began producing and destroying methane gas.

Projects must be submitted to Climate Forward no more than one year after the project start date, and the project confirmation must be completed no later than two years after the project start date. Projects may always be submitted prior to the project start date, and a project proponent may change the proposed start date prior to completion of registration of the project with the Climate Forward registry.

Project proponents are eligible to register FMUs with Climate Forward according to this methodology for a period of fifteen (15) years following the project's start date. All projects that initially pass the eligibility requirements set forth in this methodology are eligible to register FMUs through the Climate Forward registry for the duration of the project's crediting period. Project crediting periods are proposed upon project submittal and established upon successful completion of the project confirmation.

A 15-year project crediting period conforms to industry-standard minimum operational life expectancies of major BCS components. Project proponents are required to demonstrate that the life expectancy of the BCS meets or exceeds the crediting period as outlined in Sections 7 and 8. Project proponents that cannot reasonably demonstrate a 15-year life expectancy may apply for a reduced crediting period that conforms to the expected BCS lifespan specific to the project.

For projects seeking FMUs for expansion projects (Section 3.3.3.3), credits will be issued from the date the expansion was completed until the end of previously confirmed crediting period. For the purpose of this methodology, an expansion is considered complete on the date that the expanded BCS system begins producing and destroying methane gas from the additional, stabilized dairy population.

3.3 Additionality

Climate Forward registers only projects that yield surplus GHG reductions that are additional to what would have occurred in the absence of the project.

Projects must satisfy the following to be considered additional:

1. The performance standard test
2. The legal requirement test
3. Uncontrolled anaerobic baseline requirement

3.3.1 The Performance Standard Test

GHG reduction activities that are not legally required may still be non-additional if they would have been implemented for other reasons, including, for example, because they are attractive investments irrespective of the value of their GHG reductions. Performance standard tests are intended to screen out this potential set of GHG reduction activities. Standards are specified such that the large majority of projects that meet the standard are unlikely to have been implemented due to financial, economic, social, and technical or technological drivers. In other words, incentives created by the carbon market are likely to have played a critical role in decisions to implement GHG reduction activities that meet the performance standard test.

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

This methodology uses a technology-specific threshold; sometimes also referred to as a practice-based threshold, where it serves as a "best-practice standard" for managing livestock manure. By installing a BCS, or expanding one installed for an earlier project under Section 3.3.3.3, a project proponent passes the performance standard test. This installation standard is adopted from the Reserve's U.S. Livestock Project Protocol, which defined it by evaluating manure management practices in California and the United States (see Appendix C). This installation standard is also the current criterion for the California Air Resources Board (ARB) Compliance Offset Protocol for Livestock Projects.

The performance standard test is applied at the time of the project's start date, even if a project proponent develops an expansion project under Section 3.3.3.3. All projects that pass this test at the project's start date are eligible to register GHG reductions with Climate Forward for the corresponding project crediting period, even if the performance standard test is revised in subsequent versions of this methodology during that period.

3.3.2 The Legal Requirement Test

Mitigation projects are very likely to be non-additional if their implementation is required by law. The legal requirement test ensures that eligible projects and the GHG reductions they achieve would not have occurred anyway in order to comply with federal, state or local regulations, or other legally binding mandates issued by a governmental authority. A mitigation project passes the legal requirement test when there are no laws, statutes, regulations, court orders, environmental mitigation agreements, or other legally binding mandates issued by a governmental authority directly applicable to the mitigation project and requiring its implementation, or requiring the implementation of similar measures specifically at the project site that would achieve equivalent levels of GHG emission reductions.

A mitigation project passes the legal requirement test when there are no legally binding mandates issued by a governmental authority requiring the installation of a BCS or otherwise requiring the reduction or removal of methane emissions at a dairy facility ("methane reduction requirement"). If a methane reduction requirement applies, only the reductions in excess of methane reduction requirement are eligible under this methodology.

Projects submitted to Climate Forward with a project start date (or expansion completion date under Section 3.3.3.3) prior to the date that a methane reduction requirement is adopted and/or promulgated through regulations meet the legal requirement test and remain eligible for crediting for the full project crediting period. Similarly, projects registered or listed with Climate Forward prior to the date that the methane reduction requirement is adopted and/or promulgated pass the legal requirement test and remain eligible for crediting for the full project crediting period, provided the project start date is before the date on which the methane reduction requirement is implemented or becomes effective.

To satisfy the legal requirement test, project proponents must submit a signed Attestation of Legal Additionality form[6] prior to the commencement of confirmation activities.

The Reserve's analysis of manure management practices in the U.S. for the development of the U.S. Livestock Project Protocol identified no regulations that obligate livestock owners to invest in a manure BCS. The analysis looked most closely at stringent California air quality regulations (e.g., San Joaquin Valley APCD Rule 4570 and Sacramento Metropolitan AQMD Rule 496) and

[6] Attestation forms available at https://climateforward.org/program/program-and-project-forms/.

found that installing an anaerobic digester is one of several compliance options, although high capital costs appear to prevent the use of anaerobic digesters as a practical compliance mechanism for these air quality regulations.

The California Air Resources Board is pursuing anaerobic digester requirements and other air quality regulations under a Short-Lived Climate Pollution reduction strategy under California Senate Bills 605 (2014) and 1383 (2016); however, official implementation has been hampered by significant infrastructure, procurement, funding, and environmental barriers. Senate Bill 1383 set January 1, 2024 as the earliest date regulations can be implemented at livestock and dairy operations, provided the regulations are determined to be feasible, economical, cost effective, and minimize leakage. These barriers to successful implementation previously barred the Short-Lived Climate Pollution reduction strategy drafted under Senate Bill 605 from early adoption and execution in 2018 to meet aggressive targets at livestock and dairy operations beginning in 2020. While the use of anaerobic digesters is one of several compliance options, high capital costs and the likelihood of leakage appear to bar anaerobic digesters as a practical compliance mechanism under California's reduction strategy given the current policy timetable.

3.3.3 Uncontrolled Anaerobic Baseline

The installation of a BCS at a dairy operation where the primary manure management system is aerobic (produces little to no methane) may result in an increase of the amount of methane emitted to the atmosphere. Thus, the BCS must digest manure that would primarily be treated in an anaerobic system in the absence of the project for the project to be eligible to register FMUs. Sections 3.3.3.1, 3.3.3.2, and 3.3.3.3 explain the specific baseline scenario options. Under any one of these scenarios, the uncontrolled anaerobic baseline requirement may be temporarily disrupted for the purposes of construction of the project digester. In these cases, the confirmation body may use professional judgment to confirm that the requirements of this section have been met.

3.3.3.1 Existing Dairy Facilities

For dairy facilities that have been in operation prior to the project start date, the project proponent must demonstrate that an uncontrolled anaerobic manure management system was in place prior to the date that manure was first loaded into the project digester. That anaerobic system may include a lagoon, pond, or other treatment system if the design and depth of the system was sufficient to prevent algal oxygen production and create an oxygen-free bottom layer (i.e., greater than 1 meter in liquid depth).[7]

Under this baseline evaluation, if an anaerobic digester or lagoon cover was ever present and processed manure from the dairy facility, the baseline would be the digester.

3.3.3.2 New Dairy Facilities (Greenfield Projects)

Greenfield dairy projects (i.e., digester projects that are implemented concurrently with the development of a dairy facility at a site that had no prior manure management infrastructure) are eligible only if the project proponent can demonstrate that there are no restrictions to the

[7] This is consistent with the United Nations Framework Convention on Climate Change (UNFCCC) Clean Development Mechanism (CDM) methodology ACM00010 (available at: http://cdm.unfccc.int/methodologies/PAmethodologies/approved.html). For additional information on the design and maintenance of anaerobic wastewater treatment systems, see U.S. Department of Agriculture Natural Resources Conservation Service, Conservation Practice Standard, Waste Storage Facility, No. 313; and U.S. Department of Agriculture Natural Resources Conservation Service, Conservation Practice Standard, Waste Treatment Lagoon, No. 359.

construction and operation of an open, uncontrolled, anaerobic manure storage system at the dairy facility. Additionally, proponents must demonstrate that uncontrolled anaerobic storage of manure is common practice in the industry and geographic region of the digester project.

Since a greenfield project will not have an existing manure management system that can be used to model the baseline methane emissions, all greenfield projects shall utilize a set of standardized baseline management assumptions (Table B.10).

3.3.3.3 Expansion of Existing Mitigation Projects (Expansion Projects)

For project proponents that increase the BCS capacity for newly-expanded herds at projects successfully registered under this methodology, the new BCS capacity is eligible for crediting under the most current version of this methodology as a new, expanded digester project. New projects initiated under this section are eligible for FMU issuance for the increased herd count over the initial, confirmed herd numbers for the remaining years of the original project's crediting period, provided the project proponent complies with all methodology requirements in the expansion project and meets the additionality requirements specific to expansion projects.

An expansion is a continuation of the uncontrolled anaerobic baseline determined during the project confirmation (e.g., an initial greenfield project established under Section 3.3.3.2 will continue to utilize the standardized baseline management assumptions under the new, expansion project). Expansion projects must be submitted to Climate Forward during the crediting period registered in the initial project.

Expansions are confirmed separately from the initial project after the new GHG reduction activities have commenced, although the BCS construction and/or expansion can take place as a part of initial development or as a later event. Project proponents must demonstrate at the time of confirmation that the additional BCS storage capacity exceeds the capacity required for the dairy herd confirmed in the initial, registered project, and has sufficient capacity for the expanded herd size. To be eligible under this section, dairy expansions must meet or exceed fifteen percent (15%) of the baseline herd capacity confirmed in the initial mitigation project and have stabilized (monthly variance no greater than 15% from the 12-month running mean) for at least 12-months prior to commencement of confirmation activities.[8]

3.4 Environmental and Social Safeguards

It is anticipated that the implementation of projects pursuant to this methodology will only result in positive environmental and social impacts. For each project that is implemented, the project proponent shall confirm that no negative environmental and social impacts are expected, and describe any measures taken to avoid any such potential negative impacts. Furthermore, project proponents are encouraged to include information in the Project Implementation Report regarding any non-GHG benefits of the project activities to the environment or society. This may include discussion of how the project aligns with the United Nations' Sustainable Development Goals,[9] as well as additional quantification of any non-GHG benefits (such quantification is not specified by this methodology).

[8] The threshold was selected for congruity with dairy permitting requirements, which often require a permit amendment for herd increases that will exceed 15% of existing permitted levels.

[9] Additional information regarding the Sustainable Development Goals may be found online at: https://sustainabledevelopment.un.org/.

3.5 Regulatory Compliance

The project proponent must attest that no laws have been broken in carrying out project activities since the project start date, and provide an assessment of any aspects of the project which may present a risk of future regulatory violations. Where such risks are identified, the project proponent shall describe measures undertaken to reduce and/or mitigate these risks. The confirmation body shall endeavor to confirm that the project implementation did not result in any regulatory noncompliance, and also that the measures implemented to ensure no future violations occur, are appropriate in the circumstances of that particular project.

3.6 Ownership and Double Counting

The project proponent must attest that the project is not being submitted for emission reductions credit under any other carbon crediting program, world-wide. By signing the Attestation of Title, the project proponent attests that the FMUs have not and will not be registered with, reported in, held, transferred or retired via any emissions registry or inventory other than the Climate Forward registry, or registered with Climate Forward under a different project title or location. Evidence of transfer of rights of all emission reductions to the project proponent is required and must be confirmed by the confirmation body. The project proponent must provide a signed Attestation of Title document for each project, attesting to their ownership of all emission reductions generated by the project. This signed attestation, and any necessary supporting evidence, must be provided to the confirmation body. In addition to the Attestation of Title, confirmation bodies may wish to review relevant contracts, agreements, and/or supporting documentation between project proponents, end users, utilities, and other parties that may have a claim to the mitigation credits generated by the project.

3.7 Project Resilience Measures

It is assumed that without specific mitigation measures or conditions employed prior to project confirmation, there would be significant risk that a project would fail to produce, for the entire crediting period, the quantity of emission reductions estimated using this methodology. Therefore, specific mitigation measures (Project Resilience Measures) must be implemented at the time of project commencement to reduce this risk. Project proponents must provide adequate demonstration that all of the risk mitigation measures provided in Table 3.1 have been appropriately implemented. Appendix D provides expanded discussion for project longevity analyses and considerations for inclusion in this methodology.

Table 3.1. Mitigation Measures Implemented to Reduce Risk of Project Underperformance

Category	Mitigation Measures
Financial	1. Commercial contracts for long-term supply of digester products (e.g., electricity, biogas), including delivery incentives/penalties based on assumptions of stable or increasing herd size, for the duration of the crediting period.
	2. Proforma demonstration of sufficient cash flows to sustain project viability during the crediting period. Operating expenses should fall within the typical range for projects of similar type and size, and sources of working capital and project revenues must be identified.
	3. Demonstrated long-term financial stability of the BCS Owner. The BCS Owner is defined as the legal entity or entities responsible for the long-term maintenance and performance of the anaerobic digester project, including biogas utilization systems or offtake contracts for biogas supply. Long-term financial stability may be demonstrated by providing a list and discussion of historical financial records or other indications of adequate project capitalization, potentially including bank records, loans, letters of credit or other financial commitments.
Design	4. Demonstration that the primary digester and biogas utilization technologies are commercially available, proven, and appropriate for the specific project design. A Project Description must be provided that includes a list and discussion of primary anaerobic digester, biogas utilization, and emissions control technologies employed, with reference to their historical use, performance, and suitability to the project.
	5. Basis of Design documentation for the digester system including a manure volatile solids mass flow diagram and estimated annual biogas production.
Operating	6. Operations and Monitoring Plan that ensures long-term maintenance and operation of related project equipment within stated performance standards, in addition to risk mitigation measures employed and asserted for confirmation activities. At a minimum, the Operations and Monitoring Plan should meet the requirements of Section 8.2 of this methodology.
	7. Long-term service warranties or contracts that include guarantees of rapid response for project-related equipment repairs.
Dairy Closure	8. Demonstration that the project is not located within a probable range of accelerated commercial/residential development. This may include a review and discussion of historical and recent trends in land development near the project locale.
	9. Demonstrated long-term financial stability of the livestock operation. This must include a list and discussion of historical herd size, financial records or other indications of adequate livestock operation capitalization, potentially including bank records, loans, letters of credit or other financial commitments.
	10. Long-term commercial milk or animal supply contracts with delivery penalties impacted by reduced herd size, or, commercial contracts that include penalties for reducing animal numbers or manure collection/delivery quantities during the project crediting period.

3.8 Demonstration of *Ex Ante* Suitability

This methodology is suitable for *ex ante* crediting, as it provides for the complete, consistent, transparent, accurate, and conservative estimation of emission reductions from the project activities, while providing sufficient safeguards to ensure the activities continue for the duration of the crediting period. Specific safeguards to ensure projected emission reductions are realized throughout the crediting period included in Section 3.7, Project Resilience Measures, and the guidance in Section 5.3.3, Estimating Abandonment Rates and Performance Decline.

In addition, the majority of the lifetime costs of installation and operation of a BCS at a dairy operation occur up front, as capital costs of implementation. Once the BCS is operational and integrated into standard practices at the dairy, the main financial barrier has been overcome. In this context, *ex ante* crediting for the future GHG benefits is an appropriate mechanism to drive increased adoption of this type of manure management system and, thus, enhanced GHG emission reductions. The timing of the incentive corresponds to the relevant financial barrier.

4 The GHG Assessment Boundary

The GHG Assessment Boundary delineates the GHG sources, sinks, and reservoirs (SSRs) that must be assessed by project proponents in order to determine the net change in emissions caused by a project.[10]

Figure 4.1 illustrates the GHG assessment boundary for dairy projects, indicating which SSRs are included or excluded from the project boundary. Descriptions of SSRs for dairy projects, indicating which gases are included or excluded within the assessment boundary, are listed in Table 4.1.

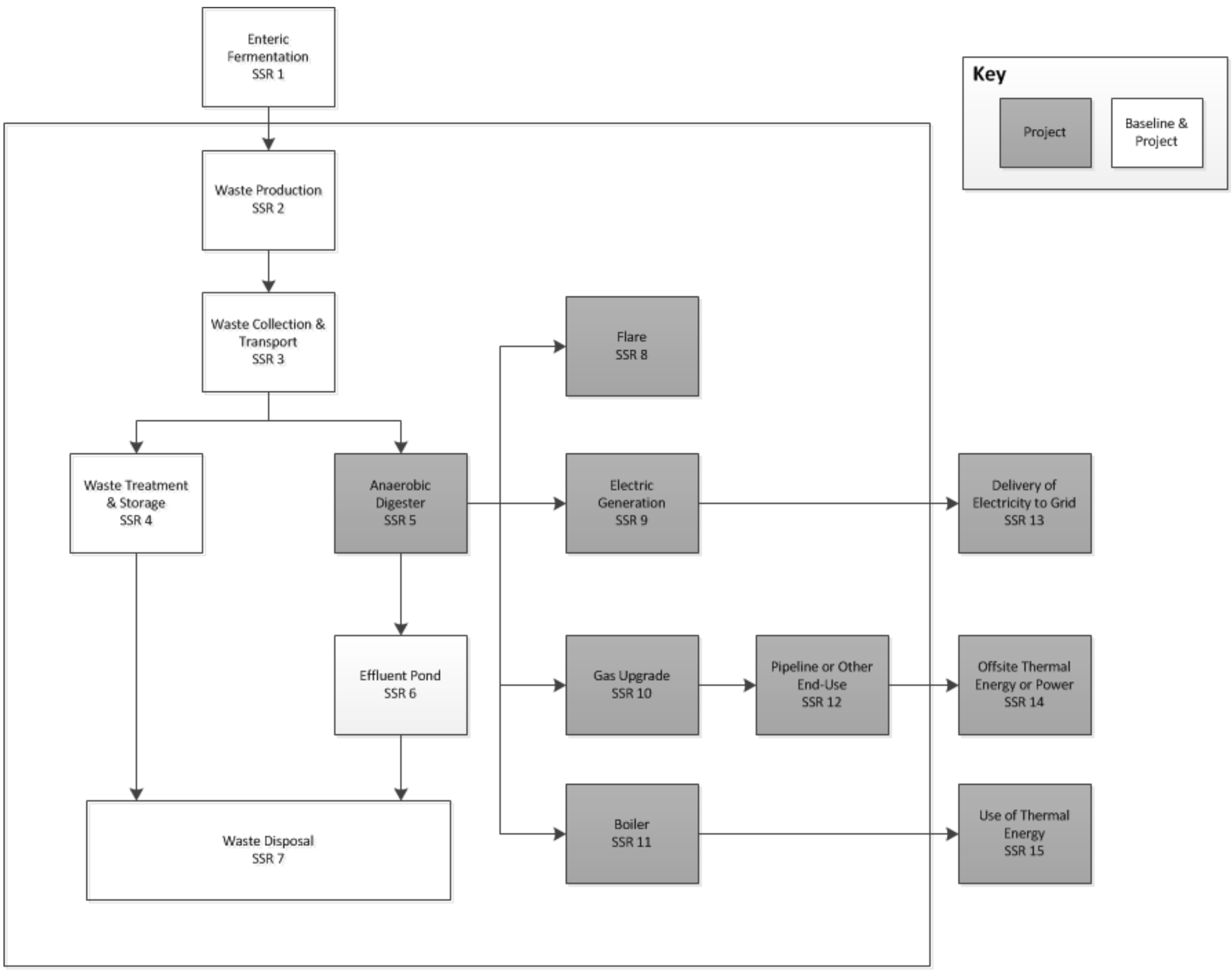

Figure 4.1. General illustration of the GHG Assessment Boundary

All SSRs within the large rectangle are included within the Assessment Boundary and must be accounted for under this methodology. Unshaded boxes represent SSRs included in the baseline and project scenarios; shaded boxes represent SSRs relevant only to project emissions. (Diagram from ARB Compliance Offset Protocol for Livestock Projects, Nov 2014).

[10] The definition and assessment of SSRs is consistent with ISO 14064-2 guidance.

Table 4.1. Description of GHG Sources, Sinks, and Reservoirs
(Adapted from ARB Compliance Offset Protocol for Livestock Projects, November 2014.)

SSR	GHG Source	GHG	Relevant to Baseline (B) or Project (P)	Included/ Excluded	Explanation
1	Emissions from enteric fermentation	CH_4	B, P	Excluded	It is very unlikely that a livestock operation would change its feeding strategy to maximize biogas production from a digester; thus impacting enteric fermentation emissions from ruminant animals.
2	Emissions from waste deposits in barn, milking parlor, or pasture/corral	N_2O	B, P	Excluded	This exclusion is conservative as emissions will either remain the same or decrease from the baseline to the project scenario.
	Emissions from mobile and stationary support equipment	CO_2	B, P	Included	If any additional vehicles or equipment are required by the project beyond what is required in the baseline, emissions from such sources shall be accounted for.
		CH_4		Excluded	Emission source is assumed to be very small.
		N_2O		Excluded	Emission source is assumed to be very small.
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	If any additional vehicles or equipment use is required by the project beyond what is required in the baseline, emissions from such sources shall be accounted for.
		CH_4		Excluded	Emission source is assumed to be very small.
		N_2O		Excluded	Emission source is assumed to be very small.
	Vehicle emissions (e.g., for manure transport from remote	CO_2		Included	If any additional vehicles or fuel use

SSR	GHG Source	GHG	Relevant to Baseline (B) or Project (P)	Included/ Excluded	Explanation
	or temporary holding)				is required by the project beyond what is required in the baseline, emissions from such equipment shall be accounted for.
		CH_4		Excluded	Emission source is assumed to be very small.
		N_2O		Excluded	Emission source is assumed to be very small.
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	Biogenic emissions are excluded.
		CH_4		Included	Primary source of emissions in the baseline.
		N_2O		Excluded	This exclusion is conservative as emissions will either remain the same or decrease from the baseline to the project scenario.
	Emissions from support equipment	CO_2		Included	If any additional equipment is required by the project beyond what is required in the baseline, emissions from such equipment shall be accounted for.
		CH_4		Excluded	Emission source is assumed to be very small.
		N_2O		Excluded	Emission source is assumed to be very small.
5	Emissions from the anaerobic digester due to biogas collection inefficiencies and venting events	CH_4	P	Included	Project may result in leaked emissions from anaerobic digester.
6	Emissions from the effluent pond	CH_4	B, P	Included	Primary source of emissions from project activities.
		N_2O		Excluded	This exclusion is conservative as emissions will either remain the same or decrease from the baseline to the

SSR	GHG Source	GHG	Relevant to Baseline (B) or Project (P)	Included/ Excluded	Explanation
					project scenario.
7	Emissions from land application	N_2O	B, P	Excluded	Project activity is unlikely to increase emissions relative to baseline activity.
	Vehicle emissions for land application and/or offsite transport	CO_2	B, P	Included	If any additional vehicle use is required by the project beyond what is required in the baseline, associated additional emissions shall be accounted for.
		CH_4		Excluded	Emission source is assumed to be very small.
		N_2O		Excluded	Emission source is assumed to be very small.
8	Emissions from combustion during flaring, including emissions from incomplete combustion of biogas	CO_2	P	Excluded	Biogenic emissions are excluded.
		CH_4		Included	Primary source of emissions from project activities.
		N_2O		Excluded	Emission source is assumed to be very small.
9	Emissions from combustion during electric generation, including incomplete combustion of biogas	CO_2	P	Excluded	Biogenic emissions are excluded.
		CH_4		Included	Primary source of emissions from project activities.
		N_2O		Excluded	Emission source is assumed to be very small.
10	Emissions from equipment upgrading biogas for pipeline injection or use as CNG/LNG fuel	CO_2	P	Included	Emissions resulting from onsite fossil fuel use and/or grid electricity may be significant.
		CH_4		Excluded	Emission source is assumed to be very small.
		N_2O		Excluded	Emission source is assumed to be very small.
11	Emissions from combustion at boiler including emissions from incomplete combustion of biogas	CO_2	P	Excluded	Emission source is assumed to be very small.
		CH_4		Included	Emissions resulting from onsite fossil

SSR	GHG Source	GHG	Relevant to Baseline (B) or Project (P)	Included/ Excluded	Explanation
					fuel use and/or grid electricity may be significant.
		N_2O		Excluded	Emission source is assumed to be very small.
12	Emissions from combustion of biogas by end user of pipeline or CNG/LNG, including incomplete combustion	CO_2	P	Excluded	Biogenic emissions are excluded.
		CH_4		Included	Primary source of emissions from project activities.
		N_2O		Excluded	Emission source is assumed to be very small.
13	Delivery and use of project electricity to grid	CO_2	P	Excluded	This methodology does not cover displacement of GHG emissions from the use of biogas-generated electricity.
		CH_4			
		N_2O			
14	Offsite thermal energy or power	CO_2	P	Excluded	This methodology does not cover displacement of GHG emissions from the use of biogas offsite.
		CH_4			
		N_2O			
15	Use of project-generated thermal energy	CO_2	P	Excluded	This methodology does not cover displacement of GHG emissions from the use of biogas offsite.
		CH_4			
		N_2O			
16	Project construction and decommissioning emissions	CO_2	P	Excluded	Emissions source assumed to be very small.
		CH_4			
		N_2O			

5 Quantifying GHG Emission Reductions

GHG emission reductions from a dairy project are quantified by comparing forecast project emissions to baseline emissions within the project boundary. Baseline emissions are an estimate of the GHG emissions from sources within the GHG Assessment Boundary (see Section 4) that would have occurred in the absence of the dairy project. Project emissions are forecasted GHG emissions that are expected to occur from sources within the GHG Assessment Boundary during the crediting period. Project emissions must be subtracted from the baseline emissions to quantify the project's total net GHG emission reductions (Equation 5.1).

GHG emission reductions for Climate Forward are quantified and confirmed at the time of project implementation. The length of time over which GHG emission reductions are quantified and forecast is called the "confirmation period." For the purposes of calculation, both baseline emissions and project emissions are quantified using annual models. The period for which GHG baseline emissions are modeled is called the "baseline calculation period"; quantification is based largely on actual and historical data. The period for which project GHG emissions are forecast is called the "project forecast period"; quantification is based on both historical data and conservative *ex ante* projections.

Some equations to calculate baseline and project emissions utilize monthly data or projections. As applicable, monthly emissions data (for baseline and project) are summed to forecast emission reductions over an annual period, which is then multiplied by the number of years in the crediting period to give total forecast emission reductions. The calculations provided in this methodology are derived from internationally accepted methodologies.[11] Project proponents shall use the calculation methods provided in this methodology to determine baseline and project GHG emissions to forecast GHG emission reductions.

Equation 5.1. Forecasted GHG Emission Reductions for a Project that Installs a Biogas Control System

$$\boldsymbol{ER = (BE - PE) \times Y_{cp} \times U_{pl}}$$

Where,

			Units
ER	=	Forecasted GHG emission reductions	tCO_2e
BE	=	Modeled annual baseline methane emissions	tCO_2e
PE	=	Forecast annual project emissions	tCO_2e
Y_{cp}	=	Number of years in the crediting period	years
U_{pl}	=	Project Longevity Adjustment Factor = 0.95 (Section 5.3.3 and Appendix D)	fraction

5.1 Required Parameters for Modeling Baseline and Project Emissions

The following parameters must be determined for the modeling of baseline and project emissions:

[11] The methodology's GHG reduction calculation method is derived from the Kyoto Protocol's Clean Development Mechanism (ACM0010 V.5), the EPA's Climate Leaders Program (Manure Offset Protocol, August 2008), the RGGI Model Rule (January 5, 2007), and the Climate Action Reserve's U.S. Livestock Project Protocol.

Livestock Population – P_L

The methodology requires project proponents to differentiate between livestock categories (L) (e.g., lactating dairy cows, non-milking dairy cows, heifers, etc.). This accounts for differences in methane generation across livestock categories. See Appendix B, Table B.2 for methane generation factors. For both baseline and project calculations, recent actual population data, spanning twelve consecutive months, is required for each livestock category. Population data must include monthly animal counts for each livestock category (herd inventory).

Baseline and project scenario calculations utilize actual population data from the twelve-month period prior to confirmation, provided the population numbers were stable (defined as a monthly variance no greater than 15% from the 12-month running mean) or increasing throughout the period (defined as a monthly variance no greater that 15% *below* the 12-month running mean). If monthly variance does not meet this requirement in the twelve-month period, calculations will utilize the actual population data from the thirty six-month period prior to confirmation. The monthly average population for each livestock category (L) will be used if the twelve-month lookback is deemed the acceptable approach for calculations; for thirty six-month lookbacks, project proponents must use the lowest average monthly population for each livestock category (L).

Volatile solids – VS_L

This value represents the daily organic material in the manure for each livestock category and consists of both biodegradable and non-biodegradable fractions. The VS content of manure is a combination of excreted fecal material (the fraction of a livestock category's diet consumed and not digested) and urine, expressed on a dry matter weight basis (kg/animal)[12]. Default VS factors for each livestock category are provided in Appendix B, Table B.2 and Table B.4.

Animal mass – $Mass_L$

This value is the annual average live weight of the animals, per livestock category. These data are necessary because default VS values are supplied in units of kg/day/1000kg mass, therefore the average mass of the corresponding livestock category is required to convert the units of VS into kg/day/animal. Site specific livestock mass is preferred for all livestock categories. If site-specific data are unavailable, Typical Animal Mass (TAM) values may be used (see Table B.2).

Maximum methane production – $B_{0,L}$

This value represents the maximum methane-producing capacity of the manure, differentiated by livestock category (L) and diet. Project proponents shall use the default B_0 factors from Table B.3.

Management system manure fraction – MS_S

The MS value apportions manure from each livestock category to appropriate manure management system component (S) and is a critical factor in determining a project baseline, as well as project emissions from effluent treatment. It reflects the reality that waste from the operation's livestock categories are not managed uniformly. The MS value accounts for the operation's multiple types of manure management systems. It is expressed as a percent (%), relative to the total amount of VS produced by the livestock category. As waste production is normalized for each livestock category, the percentage shall be calculated as percent of population for each livestock category. For example, a dairy operation might send 85% of its

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

milking cows' waste to an anaerobic lagoon and 15% could be deposited in a corral. In this situation, an MS value of 85% would be assigned to Equation 5.6 and 15% to Equation 5.9.

Importantly, the MS value indicates where the waste would have been managed in the baseline scenario. If a portion of the VS was removed from the waste stream through a separation procedure, the MS value shall be adjusted to accurately reflect the baseline treatment of the VS. To account for VS removal from solids separation equipment, project proponents may use a default value for the type of separation mechanisms employed (Table B.9), or a site-specific value based on the removal efficiency of the baseline system.

MS_{BCS}, which represents the fraction of manure that is sent to the BCS in the project scenario, follows the same logic as above, but is used to accurately quantify the project methane emissions from effluent treatment (see Equation 5.13).

Methane conversion factor – MCF[13]

This factor reflects the site-specific annual or monthly biological conversion of manure volatile solids to methane for each of the dairy operation's manure storage and treatment systems, as predicted using the van't Hoff-Arrhenius equation or default regional values, and the most recent ten-year historical monthly average of ambient temperatures specific to the project location from the nearest official weather monitoring station.[14]

Each manure management system component has a volatile solids-to-methane conversion efficiency that represents the degree to which maximum methane production (B_0) is achieved. Methane production is a function of the extent of anaerobic conditions present in the system, the temperature of the system, and the retention time of organic material in the system.[15]

Default MCF values for non-anaerobic baseline manure management system components (as well as certain project BCS effluent treatment and Non-BCS sources) are available in Appendix B. These are used in and Equation 5.9.

In contrast, site-specific calculations of volatile solids-to-methane conversion efficiency are required for anaerobic baseline manure management system components and for the anaerobic treatment of project BCS effluent. For anaerobic lagoons, storage ponds, liquid slurry tanks, and other anaerobic storage solutions, project proponents perform a site-specific calculation of the mass of volatile solids degraded by the anaerobic storage/treatment system. This is expressed as "degraded volatile solids" or VS_{deg} in Equation 5.4, which equals the system's monthly available volatile solids multiplied by 'f', the van't Hoff-Arrhenius factor. The 'f' factor effectively converts total available volatile solids in the anaerobic manure storage/treatment system to methane-convertible volatile solids, based on the monthly temperature of the system. The

[13] Anaerobic digesters commonly used at livestock operations in the United States are typically designed with hydraulic retention times and process controls to convert about eighty percent (80%) of the input manure volatile solids to methane. However, depending largely on management effort, digesters occasionally suffer equipment or process disruptions that result in reduced methane conversion. Consistent with current Reserve and ARB livestock project emission reduction quantification methodologies, a conservative default methane conversion factor (MCF_{BCS}) of seventy percent (70%) will be used in the calculation of methane production by the BCS to address the risk of digester underperformance. Risk assessment as outlined in Section 6 will not be required for this factor; however, the project proponent must demonstrate during confirmation that the anaerobic digestion system is designed with adequate capacity (hydraulic retention time relative to process type) to digest manure VS input from the modeled livestock population at rates at or above this factor threshold.
[14] The method is derived from Mangino et al., "Development of a Methane Conversion Factor to Estimate Emissions from Animal Waste Lagoons" (2001).
[15] *IPCC 2006 Guidelines* volume 4, chapter 10, p. 10.42.

multiplication of VS_{deg} by B_0 quantifies the maximum potential methane emissions that would have been produced for each livestock category's contribution of manure to that system.

5.2 Estimating Baseline GHG Emissions

Baseline emissions represent the GHG emissions within the GHG Assessment Boundary that would have occurred if not for the installation of the BCS. For the purposes of this methodology, project proponents calculate their baseline emissions according to the manure management system in place prior to installing the BCS. For Greenfield projects, as defined in Section 3.3.3.2, the baseline manure management practices shall be modeled according to the assumptions provided in Table B.10.

Equation 5.2. Modeled Baseline Emissions

$$BE = BE_{CH_4} + BE_{CO_2}$$

Where,

			Units
BE	=	Modeled annual baseline methane emissions	tCO_2e
BE_{CH4}	=	Modeled annual baseline CH_4 emissions	tCO_2e
BE_{CO2}	=	Modeled annual baseline CO_2 emissions	years

5.2.1 Baseline Methane Emissions

The procedure to determine the modeled baseline methane emissions follows, which incorporates Equation 5.4 through Equation 5.9. The calculation procedures use a combination of site-specific values and default factors. Calculations of methane emissions for both baseline and project scenarios are based on common volatile solids production values (Figure 5.1).

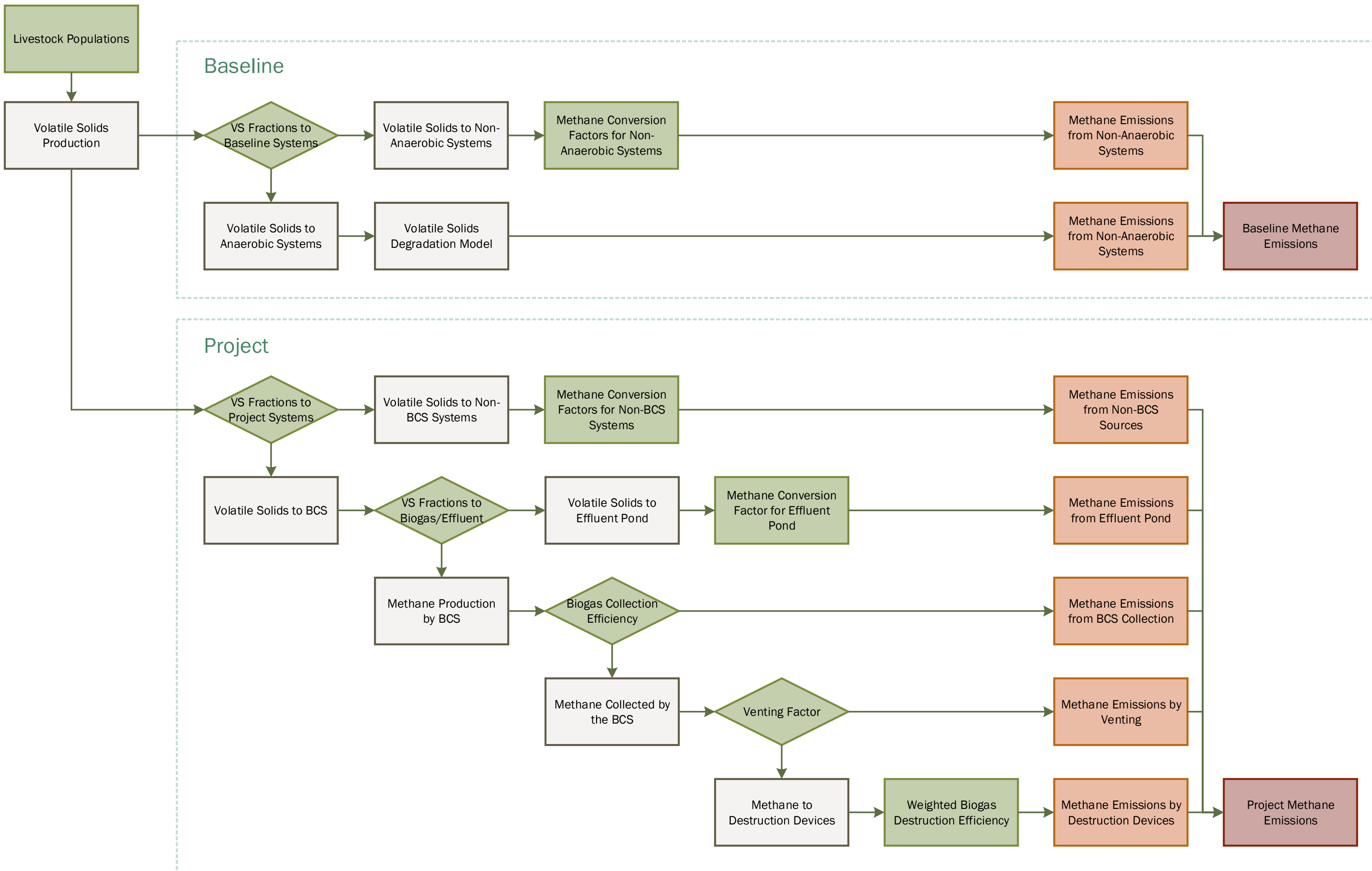

Figure 5.1. Calculation of Baseline and Project Methane Emissions Based on Livestock Manure Volatile Solids Production

Equation 5.3. Modeled Annual Baseline Methane Emissions

$$BE_{CH_4} = \sum_{AS} BE_{CH_4,AS} + \sum_{nAS} BE_{CH_4,nAS}$$

Where, Units

BE_{CH4}	=	Annual project baseline methane emissions	tCO_2e
$BE_{CH4,AS}$	=	Annual baseline methane emissions for each baseline anaerobic storage/treatment system	tCO_2e
$BE_{CH4,nAS}$	=	Annual baseline methane emissions for each baseline non-anaerobic storage/treatment system	tCO_2e
AS	=	Anaerobic storage/treatment systems	
nAS	=	Non-anaerobic storage/treatment systems	

5.2.2 Retention of Volatile Solids

Equation 5.4 through Equation 5.6 calculate methane emissions from anaerobic manure storage/treatment systems based on site-specific information on the mass of volatile solids degraded by the anaerobic storage/treatment system and available for methane conversion. Calculations incorporate the effects of temperature through the van't Hoff-Arrhenius (f) factor (see Equation 5.7) and account for the retention of volatile solids using monthly assumptions of baseline conditions. Equation 5.8 describes the calculation of VS production by livestock. Each month, a certain quantity of VS is converted into methane (VS_{deg}). The VS that is available for conversion each month (VS_{avail}) is the sum of VS that enters the manure management system, as well as VS that remains in the system from the previous month ($VS_{avail,m-1}$ – $VS_{deg,m-1}$). Volatile solids carryover in the first month of the both the baseline calculation period and the project forecast period models should reflect carryover from the last month of the period models, at equilibrium (i.e., adjusted iteratively so that the volatile solids carryover to the first month is equal to the volatile solids remaining at the end of the last month).

Project proponents shall not carry over volatile solids from one month to the next when modeling baseline anaerobic treatment systems where the retention time was 30 days or less. For these systems ($VS_{avail,m-1}$ – $VS_{deg,m-1}$) = 0 in Equation 5.6 for every month.

Depending on the accumulation of sludge in the baseline manure storage system, it may have been necessary to drain and clean the system on a periodic basis. This cleaning removes the non-degraded VS that has accumulated in the system. For anaerobic lagoons with a retention time greater than 30 days, project developers shall zero out the VS retained in the system following the month when the system would have been completely drained and sludge removed under baseline operating conditions. For the month following the sludge removal, ($VS_{avail,m-1}$ – $VS_{deg,m-1}$) = 0 in Equation 5.6. For projects where a BCS is being retrofit into existing operations, baseline anaerobic system management practices should reflect actual pre-project manure management practices on that farm.

If the farm utilized solids separation in the baseline (thus preventing or delaying sludge accumulation), this removal and alternative treatment of VS should be reflected in the MS values, as explained earlier in this section.

The removal of supernatant liquids for spraying on fields at agronomic rates does not affect the monthly carryover of VS provided the system maintains at least one meter of liquid depth.

Projects therefore do not need to account for regular field spraying activities that meet this description.

Equation 5.9 applies to non-anaerobic storage/treatment systems. Both Equation 5.3 and Equation 5.4 reflect basic biological principles of methane production from available volatile solids, determine methane generation for each livestock category, and account for the extent to which the waste management system handles each category's manure.

Equation 5.4. Modeled Annual Baseline Methane Emissions from Anaerobic Storage/Treatment Systems

$$BE_{CH_4,AS} = \sum_{L,m} \left(VS_{deg,AS,L,m} \times B_{0,L} \right) \times D_{CH_4} \times C_{Mg/kg} \times GWP_{CH_4}$$

Where,

			Units
$BE_{CH4,AS}$	=	Annual baseline methane emissions from baseline anaerobic storage/treatment system *AS*	tCO_2e
$VS_{deg,AS,L,m}$	=	Monthly volatile solids degraded in anaerobic storage/treatment system *AS* for each livestock category and month	kg dry matter
$B_{0,L}$	=	Maximum methane producing potential of manure for each livestock category	m^3CH_4/kg VS
D_{CH4}	=	Density of methane (1 atm, 60°F) = 0.68	kg/m^3
$C_{Mg/kg}$	=	Conversion factor, kg to Mg = 1×10^{-3}	Mg/kg
GWP_{CH4}	=	Global warming potential of methane	tCO_2e/tCH_4
AS	=	Anaerobic storage/treatment system	
L	=	Livestock category	
m	=	Month in the baseline calculation period	month

Equation 5.5. Calculation of Volatile Solids Degraded Monthly in Baseline Anaerobic Storage/Treatment Systems

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

Where,

			Units
$VS_{deg,AS,L,m}$	=	Monthly volatile solids degraded available for degradation in anaerobic storage/treatment system *AS* for each livestock category and month	kg dry matter
$VS_{avail,AS,L,m}$	=	Monthly volatile solids available for degradation in the previous month in anaerobic storage/treatment system *AS* for each livestock category and month	kg dry matter
f	=	van 't Hoff-Arrhenius factor[16] Monthly volatile solids degraded in the previous month in anaerobic storage/treatment system *AS* for each livestock category	
AS	=	Anaerobic storage/treatment system	
L	=	Livestock category	
m	=	Month in the baseline calculation period	month

[16] Mangino, et al.

Equation 5.6. Calculation of Volatile Solids Available Monthly for Degradation in Baseline Anaerobic Storage/Treatment Systems

$$\boldsymbol{VS_{avail,AS,L,m} = \left(VS_L \times P_{L,m} \times MS_{AS,L} \times d_m \times MDP\right) + \left(VS_{avail,AS,L,m-1} - VS_{deg,AS,L,m-1}\right)}$$

Where,

			Units
$VS_{avail,AS,L,m}$	=	Monthly volatile solids available for degradation in anaerobic storage/treatment system *AS* for each livestock category and month	kg dry matter
VS_L	=	Volatile solids excreted by livestock category *L*	kg dry matter/ animal·day
$P_{L,m}$	=	Monthly average population of livestock category *L*	animals
$MS_{AS,L}$	=	Fraction of volatile solids sent to (managed in) anaerobic manure storage/treatment system *AS* from each livestock category[17]	fraction (0–1)
d_m	=	Number of days in each month	days
MDP	=	Model calibration factor for management and design practices = 0.8[18]	
$VS_{avail,AS,L,m-1}$	=	Monthly volatile solids available for degradation in the previous month in anaerobic storage/treatment system *AS* for each livestock category[19]	kg dry matter
$VS_{deg,AS,L,m-1}$	=	Monthly volatile solids degraded in the previous month in anaerobic storage/treatment system *AS* for each livestock category	kg dry matter
AS	=	Anaerobic storage/treatment system	
L	=	Livestock category	
m	=	Month in the baseline calculation period	month

[17] The MS value represents the percent of manure that would be sent to (managed by) the anaerobic manure storage/treatment systems in the baseline case – as if the biogas control system was never installed.
[18] Mangino, et al. This factor was derived to "account for management and design practices that result in the loss of volatile solids from the management system." This reflects the difference between the theoretical modeled biological activity and empirical measurement of biological activity due to removal of liquid or other management practices that result in loss of VS from the treatment system. This does not account for removal of solids prior to the treatment system.
[19] *IPCC 2006 Guidelines* (Volume 4, Chapter 10, p. 42); ACM0010 (V2, p.8); and EPA Climate Leaders Manure Offset Protocol (August 2008).

Equation 5.7. Calculation of van ’t Hoff-Arrhenius Factor

$$f = \begin{cases} min\left(exp\left[\frac{E(T_{amb} - T_{max})}{R \times T_{max} \times T_{amb}}\right], f_{max}\right), if\ T_{amb} \geq 278 \\ 0.104, \quad if\ T_{amb} < 278 \end{cases}$$

Where,			Units
f	=	van ’t Hoff-Arrhenius factor	fraction
E	=	Activation energy constant = 15,175	cal/mol
T_{max}	=	Temperature of maximum reaction rate constant = 303.16	Kelvin
T_{amb}	=	Monthly average ambient temperature	Kelvin
R	=	Ideal gas constant = 1,987	cal/Kelvin·mol
f_{max}	=	Maximum f factor = 0.95	fraction

The equation can be read as*: if the ambient temperature is greater than or equal to 278 K, then f is equal to the minimum of the van ‘t Hoff-Arrhenius function or the maximum f factor; otherwise, f is equal to 0.104. The calculated f value is constrained to the range 0.104 – 0.950.*

Equation 5.8. Calculation of Livestock Volatile Solids Excretion

$$VS_L = VSR_L \times Mass_L \times C_{Mg/kg}$$

Where,			Units
VS_L	=	Volatile solids excreted by livestock category *L*	kg dry matter/ animal·day
VSR_L	=	Default volatile solids excretion rate for livestock category *L* (Table B.2 or Table B.4)	kg dry matter/Mg animal mass·day
$Mass_L$	=	Average live weight for livestock category *L*; if site specific data is unavailable, use default values from Table B.2	kg animal mass/animal
$C_{Mg/kg}$	=	Conversion factor, kg animal mass to Mg animal mass = 1×10^{-3}	Mg/kg

Equation 5.9. Modeled Baseline Methane Emissions for Non-Anaerobic Storage/Treatment Systems

$$BE_{CH_4,nAS} = \sum_{L,m}\left(P_{L,m} \times MS_{nAS,L} \times VS_L \times d_m \times MCF_{nAS} \times B_{0,L}\right) \times D_{CH_4} \times C_{Mg/kg} \times GWP_{CH_4}$$

Where,

			Units
$BE_{CH4,nAS}$	=	Annual baseline methane emissions from baseline non-anaerobic storage/treatment system *nAS*	tCO_2e
$P_{L,m}$	=	Average population size of livestock category *L* for each month	animals
$MS_{nAS,L}$	=	Fraction of volatile solids sent to (managed in) non-anaerobic manure storage/treatment system *nAS* from each livestock category	fraction (0–1)
VS_L	=	Volatile solids excreted by livestock category *L*	kg dry matter/ animal·day
d_m	=	Number of days in each month	days
MCF_{nAS}	=	Methane conversion factor for non-anaerobic treatment system *nAS*	fraction (0–1)
$B_{0,L}$	=	Maximum methane producing potential of manure volatile solids for each livestock category	m^3CH_4/kg VS
D_{CH4}	=	Density of methane (1 atm, 60°F) = 0.68	kg/m^3
$C_{Mg/kg}$	=	Conversion factor, kg to Mg = 1×10^{-3}	Mg/kg
GWP_{CH4}	=	Global warming potential of methane	tCO_2e/tCH_4
nAS	=	Non-anaerobic storage/treatment system	
L	=	Livestock category	
m	=	Month in the baseline calculation period	month

5.2.3 Baseline CO_2 Emissions

Sources of carbon dioxide emissions associated with a dairy operation within the GHG Assessment Boundary (Figure 4.1) may include grid electricity use by pumps and equipment, fossil fuel generators used to power pumping systems or milking parlor equipment, tractors that operate in barns or free-stalls, onsite manure hauling trucks, or vehicles that transport manure offsite.

Project proponents shall use Equation 5.10 to calculate baseline project emissions using fuel and electricity invoices or other documentation for the baseline calculation period, or, if they can demonstrate during project confirmation that project carbon dioxide emissions are estimated to be equal to or less than 5% of the total baseline emissions, then the project proponent may estimate baseline and project carbon dioxide emissions. If an estimation method is used, the confirmation body shall confirm based on professional judgment that project carbon dioxide emissions are equal to or less than 5% of the total baseline emissions based on documentation and the estimation methodology provided by the project proponent. Regardless of the method used, all estimates or calculations of anthropogenic carbon dioxide emissions within the GHG Assessment Boundary must be confirmed and included in emission reduction calculations.

Equation 5.10. Modeled Annual Baseline CO_2 Emissions

$$BE_{CO_2} = \left(\sum_{E} Q_{E,grid} \times EF_{grid}\right) + \left(\sum_{F} Q_{F,fuel} \times EF_{fuel} \times C_{Mg/kg}\right)$$

Where,

			Units
BE_{CO2}	=	Modeled annual baseline CO_2 emissions	tCO_2
$Q_{E,grid}$	=	Quantity of grid-connected electricity consumed for each emissions source *E* during the baseline calculation period	MWh
EF_{grid}	=	eGrid emission factor for grid electricity consumed	tCO_2/MWh
$Q_{F,fuel}$	=	Quantity of fossil fuel consumed for each mobile and stationary combustion source *F* during the baseline calculation period	MMBtu or gal
EF_{fuel}	=	Fuel-specific emission factor, from Table B.8	$kgCO_2$/ MMBtu or gal
$C_{Mg/kg}$	=	Conversion factor, kg to Mg = 1×10^{-3}	Mg/kg

5.3 Estimating Project GHG Emissions

Project emissions are forecasted GHG emissions that are expected to occur within the GHG assessment boundary after the installation of the BCS. Project emissions calculated *ex ante* for a twelve-month “project forecast period” assumed to be representative of the entire crediting period.

Equation 5.11 describes the calculation of annual project emissions. Equation 5.12 through Equation 5.20 describe calculations for project methane emissions. Equation 5.21 describes calculation of project CO_2 emissions.

Equation 5.11. Forecast Annual Project Emissions

$$PE = PE_{CH_4} + PE_{CO_2}$$

Where,

			Units
PE	=	Forecast annual project methane emissions	tCO_2e
PE_{CH4}	=	Forecast annual project CH_4 emissions	tCO_2e
PE_{CO2}	=	Modeled annual project CO_2 emissions	tCO_2e

5.3.1 Estimating Project Methane Emissions

Consistent with the methodology’s baseline methane calculation approach, the formula to account for project methane emissions incorporates all potential sources within the waste treatment and storage category. As shown in Equation 5.12, project methane emissions include:

- Methane created by the BCS that is not captured and destroyed by the control system
- Methane from the digester effluent treatment systems, both anaerobic and non-anaerobic (where applicable)
- Methane from sources in the manure storage and treatment systems other than the BCS and associated effluent treatment systems. This includes all other manure treatment systems such as compost piles, solids storage, etc.

Equation 5.12. Forecast Annual Project Methane Emissions

$$PE_{CH_4} = \left(PE_{CH_4,BCS} + PE_{CH_4,ET_{AS}} + PE_{CH_4,ET_{nAS}} + PE_{CH_4,nBCS}\right) \times GWP_{CH_4}$$

Where,			Units
PE_{CH4}	=	Forecast annual project methane emissions	tCO_2e
$PE_{CH4,BCS}$	=	Forecast annual methane emissions from the biogas control system	tCH_4
$PE_{CH4,ETAS}$	=	Forecast annual methane emissions from anaerobic storage/treatment systems receiving BCS effluent, as quantified in Equation 5.17	tCH_4
$PE_{CH4,ETnAS}$	=	Forecast annual methane emissions from non-anaerobic storage/treatment systems receiving BCS effluent	tCH_4
$PE_{CH4,nBCS}$	=	Forecast annual methane emissions from manure storage/treatment systems other than the BCS and associated effluent treatment systems	tCH_4
GWP_{CH4}	=	Global warming potential of methane	tCO_2e/tCH_4

5.3.1.1 Methane Emissions from the Biogas Control System

Annual methane production by the project BCS is forecast based on the quantity of volatile solids degraded in the anaerobic digester(s) during the project forecast period, and a conservative default methane conversion factor (Equation 5.13). Calculations assume the same monthly livestock populations and average ambient temperatures as used in baseline calculations.

Methane emissions from the BCS are calculated using Equation 5.14 and Equation 5.15. Calculations utilize a default BCS biogas collection efficiency, based on digester type, and a forecast overall biogas destruction efficiency, weighted by proportional biogas flow through each destruction device.

Although not common under normal digester operations, it is possible that planned venting events may occur during the crediting period. Sources of methane venting are various and may be due to maintenance on digester cover materials, the digester vessel, or the gas collection system during the crediting period. Additionally, project proponents should account for vented emissions due to partial system collection and destruction design (i.e., surplus biogas is vented instead of combusted by an auxiliary system). To account for the probability of planned events, methane emissions due to venting are estimated by the project proponent for the project forecast period and included in Equation 5.16.

Equation 5.13. Forecast Monthly Methane Production by the Project BCS

$$BCS_{CH_4,prod,m} = \sum_{L} (P_{L,m} \times VS_L \times MS_{BCS,L} \times d_m \times MCF_{BCS} \times B_{0,L}) \times D_{CH_4} \times C_{Mg/kg}$$

Where,

			Units
$BCS_{CH4,prod,m}$	=	Forecast annual methane production by the BCS	tCH_4
$P_{L,m}$	=	Average population size of livestock category *L* for each month	animals
VS_L	=	Volatile solids excreted by livestock category *L*	kg dry matter/ animal·day
$MS_{BCS,L}$	=	Fraction of volatile solids sent to (managed in) the BCS from each livestock category in the project scenario	fraction (0–1)
d_m	=	Number of days in month	days
MCF_{BCS}		Methane Conversion Factor for the BCS = 0.70	fraction (0–1)
$B_{0,L}$	=	Maximum methane producing potential of manure volatile solids for each livestock category	m^3CH_4/kg VS
D_{CH4}	=	Density of methane (1 atm, 60°F) = 0.68	kg/m^3
$C_{Mg/kg}$	=	Conversion factor, kg to Mg = 1×10^{-3}	Mg/kg
L	=	Livestock category	
m	=	Month in the project forecast period	month

Equation 5.14. Forecast Annual Project Methane Emissions from the BCS

$$PE_{CH_4,BCS} = \sum_{m} \left[BCS_{CH_4,prod,m} \times \left(1 - (BCE \times BDE_{BCS,m})\right)\right] + BCS_{CH_4,vent,m}$$

Where,

			Units
$PE_{CH4,BCS}$	=	Forecast annual methane emissions from the biogas control system	tCH_4
$BCS_{CH4,prod,m}$	=	Forecast monthly methane production by the BCS, as quantified in Equation 5.13	tCH_4
BCE	=	Biogas collection efficiency of the BCS, from Appendix B	fraction (0–1)
$BDE_{BCS,m}$	=	Forecast overall monthly methane destruction efficiency of the BCS, as quantified in Equation 5.15	fraction (0–1)
$BCS_{CH4,vent,m}$	=	Forecast annual quantity of methane vented to the atmosphere due to venting events, as quantified in Equation 5.16	tCH_4

Equation 5.15. Forecast Overall Monthly Methane Destruction Efficiency of the Project BCS

$$\boldsymbol{BDE_{BCS,m} = \sum_{DD,m} \left(BDE_{DD} \times FP_{DD,m}\right)}$$

Where,

			Units
$BDE_{BCS,m}$	=	Forecast overall monthly methane destruction efficiency of the BCS	fraction (0–1)
BDE_{DD}	=	Default device biogas destruction efficiency for destruction device *DD*, from Appendix B	fraction (0–1)
$FP_{DD,m}$	=	Forecast monthly percentage of total biogas flow to destruction device *DD*	fraction (0–1)
DD	=	Destruction device	
m	=	Month in the project forecast period	month

Equation 5.16. Forecast Annual Quantity of Methane Vented by the Project

$$\boldsymbol{BCS_{CH_4,vent,m} = \left(BCS_{CH_4,prod,m}\right) \times \left(V_f\right)}$$

Where,

			Units
$BCS_{CH4,vent,m}$	=	Forecast monthly quantity of methane vented to the atmosphere due to venting events	tCH_4
$BCS_{CH4,prod,m}$	=	Forecast monthly methane production by the BCS	tCH_4
V_f	=	Methane venting factor (site-specific, see Table 6.1)	fraction (0–1)

5.3.1.2 Methane Emissions from the BCS Effluent Treatment Systems

Methane emissions from all storage/treatment systems associated with the management of BCS effluent are calculated as in Equation 5.17 through Equation 5.19. Anaerobic effluent treatment systems are those which store liquid effluent in a lagoon, pond, or tank. This includes liquid storage systems that employ non-airtight covers (i.e., biogas is freely vented to the atmosphere) as long as the entire system is managed as a passive storage system, rather than an actively-managed treatment system (e.g., no heating, mixing, etc.).

If the project includes the installation of an impermeable cover on an effluent pond (potentially creating an additional anaerobic digester) and the biogas generated in this covered pond is collected and destroyed by the project BCS, then this covered pond shall be considered part of the project digester system. If the biogas generated by this covered pond is not destroyed, it must be quantified as project methane emissions using Equation 5.17.

The factor ETF_{ET} shall be estimated by the project proponent as the fraction of effluent VS exiting the digester is input to each effluent treatment system ‘ET’, and is used to calculate the quantity of effluent VS entering the effluent treatment systems (Equation 5.18). In other respects, the calculation approach for quantifying methane emissions from anaerobic storage/treatment systems receiving BCS effluent is similar to that used for baseline anaerobic manure storage/treatment systems.

Equation 5.17. Forecast Annual Project Methane Emissions from Anaerobic Storage/Treatment Systems Receiving BCS Effluent

$$PE_{CH_4,ET_{AS}} = \sum_{ET_{AS},L,m} \left(VS_{ET_{AS},L,m} \times B_{0,L} \times d_m \times MDP \times f_m \times D_{CH_4} \times C_{Mg/kg}\right)$$

Where,

			Units
$PE_{CH4,ETAS}$	=	Forecast annual methane emissions from anaerobic storage/treatment systems receiving BCS effluent	tCH_4
$VS_{ETAS,L,m}$	=	Forecast volatile solids input to anaerobic effluent treatment system *ET* for month *m*	kg dry matter/ day
$B_{0,L}$	=	Maximum methane producing potential of manure volatile solids for livestock category *L*	m^3CH_4/kg VS
d_m	=	Number of days in each month	days
MDP	=	Model calibration factor for management and design practices = 0.8	
f_m	=	van ’t Hoff-Arrhenius factor for each month in the project forecast period, using historical 10-year average monthly temperatures; calculation as in Equation 5.7	fraction
D_{CH4}	=	Density of methane (1 atm, 60°F) = 0.68	kg/m^3
$C_{Mg/kg}$	=	Conversion factor, kg to Mg = 1×10^{-3}	Mg/kg
ET_{AS}	=	Anaerobic effluent treatment system	
L	=	Livestock category	
m	=	Month in the project forecast period	month

Equation 5.18. Forecast Quantity of Volatile Solids Input Daily to Effluent Treatment Systems in the Project Scenario

$$VS_{ET,L,m} = \left(P_{L,m} \times VS_L \times MS_{BCS,L,m}\right) \times (1 - MCF_{BCS}) \times ETF_{ET}$$

Where,

			Units
$VS_{ET,L,m}$	=	Forecast quantity of volatile solids input daily to effluent treatment system *ET* in month *m*	kg dry matter/ day
$P_{L,m}$	=	Average population size of livestock category *L* for the project forecast period in month *m*	animals
VS_L	=	Volatile solids excreted by livestock category *L*	kg dry matter/ animal·day
$MS_{BCS,L,m}$	=	Fraction of volatile solids sent to (managed in) the BCS from each livestock category in the project forecast period in month *m*	fraction (0–1)
MCF_{BCS}		Methane conversion factor for the BCS = 0.70	fraction (0–1)
ETF_{ET}	=	Fraction of effluent that exits the digester and is input directly to the effluent treatment system *ET*	fraction (0–1)
ET	=	Effluent treatment system	

Equation 5.19. Forecast Annual Project Methane Emissions from Non-Anaerobic Storage/Treatment Systems Receiving BCS Effluent[20]

$$PE_{CH_4,ET_{nAS}} = \sum_{ET_{nAS}} \left(VS_{ET_{nAS}} \times B_{0,ET_{nAS}} \times d_p \times MCF_{ET_{nAS}} \times D_{CH_4} \times C_{Mg/kg} \right)$$

Where,			Units
$PE_{CH4,ETnAS}$	=	Forecast annual methane emissions from non-anaerobic storage/treatment systems receiving BCS effluent	tCH_4
VS_{ETnAS}	=	Forecast volatile solids input to non-anaerobic effluent treatment system *ET*	kg dry matter/ day
$B_{0,ETnAS}$	=	Maximum methane producing potential of manure volatile solids for non-anaerobic effluent treatment system *ET*[21]	m^3CH_4/kg VS
d_p	=	Number of days in the project forecast period	days
MCF_{ETnAS}	=	Methane conversion factor for the non-anaerobic effluent treatment system	
D_{CH4}	=	Density of methane (1 atm, 60°F) = 0.68	kg/m^3
$C_{Mg/kg}$	=	Conversion factor, kg to Mg = 1×10^{-3}	Mg/kg
ET_{nAS}	=	Non-anaerobic effluent treatment system	

5.3.1.3 Methane Emissions from Non-BCS Sources

Calculation of methane emissions from non-BCS-related sources[22] follows the approach provided in the baseline methane equations. Several activity data for the variables in Equation 5.12 to Equation 5.20 will be the same as those in Equation 5.9.

[20] Non-anaerobic effluent treatment systems are those which manage effluent in solid form, or those which manage liquid effluent in a way that would be considered aerobic (e.g., a pond with effective aeration equipment).
[21] The B_0 value for the project effluent pond is not differentiated by livestock category. Project proponents shall use the B_0 value that corresponds with a weighted average of the operation's livestock categories that contribute manure to the BCS (weighted by the kg of VS contributed by each livestock category). Supporting laboratory data and documentation need to be supplied to the confirmation body to justify an alternative value.
[22] According to this methodology, non-BCS-related sources means manure management system components (system component 'S') other than the biogas control system and the BCS effluent treatment systems (if used).

Equation 5.20. Forecast Annual Project Methane Emissions from Non-BCS-Related Sources

$$PE_{CH_4,nBCS} = \sum_{nBCS,L} \left(P_L \times VS_L \times MS_{nBCS,L} \times B_{0,L} \times MCF_{nBCS}\right) \times d_p \times D_{CH_4} \times C_{Mg/kg}$$

Where,			Units
$PE_{CH4,nBCS}$	=	Forecast annual project methane emissions from non-BCS-related sources	tCH_4
P_L	=	Average population size of livestock category *L* for the project forecast period	animals
VS_L	=	Forecast volatile solids input to non-BCS-related source *nBCS*	kg dry matter/ day
$MS_{nBCS,L}$	=	Fraction of volatile solids sent to (managed in) non-BCS-related sources from each livestock category in the project forecast period	fraction (0–1)
$B_{0,L}$	=	Maximum methane producing potential of manure volatile solids for non-anaerobic effluent treatment system *ET*	m^3CH_4/kg VS
MCF_{nBCS}	=	Methane conversion factor for the non-BCS related source *nBCS*	
d_p	=	Number of days in the project forecast period	days
D_{CH4}	=	Density of methane (1 atm, 60°F) = 0.68	kg/m^3
$C_{Mg/kg}$	=	Conversion factor, kg to Mg = 1×10^{-3}	Mg/kg

5.3.2 Project CO_2 Emissions

Per Table 4.1, the carbon dioxide emissions from any additional equipment, vehicles, or fuel use that is required by the project beyond what is required in the baseline shall be accounted for. In practice, project developers shall forecast the emissions from any new electric- or fuel-powered equipment or vehicles purchased and installed/operated specifically for the purpose of implementing the project, as well as any additional fuel used by old or new vehicles to collect or transport waste (Equation 5.21).

Equation 5.21. Annual Project CO_2 Emissions from Electricity and Fossil Fuel Use

$$EFF_{CO_2} = \left(\sum_E Q_{E,grid} \times EF_{grid}\right) + \left(\sum_F Q_{F,fuel} \times EF_{fuel} \times C_{Mg/kg}\right)$$

Where,

			Units
EFF_{CO2}	=	Annual project CO_2 emissions from electricity and fossil fuel use	tCO_2
$Q_{E,grid}$	=	Quantity of grid-connected electricity consumed for each emissions source *E* during the project forecast period	MWh
EF_{grid}	=	eGrid emission factor for grid electricity consumed[23]	tCO_2/MWh
$Q_{F,fuel}$	=	Quantity of fossil fuel consumed for each mobile and stationary combustion source *F* during the project forecast period	MMBtu or gal
EF_{fuel}	=	Fuel-specific emission factor, from Appendix B	$kgCO_2$/ MMBtu or gal
$C_{Mg/kg}$	=	Conversion factor, kg to Mg = 1×10^{-3}	Mg/kg

Equation 5.22. Forecast Annual Project CO_2 Emissions

$$PE_{CO_2} = BE_{CO_2} + \left(EFF_{CO_2} - BE_{CO_2}\right)$$

Where,

			Units
PE_{CO2}	=	Forecast annual project CO_2 emissions	tCO_2
EFF_{CO2}	=	Forecast annual project CO_2 emissions from electricity and fossil fuel use	tCO_2
BE_{CO2}	=	Modeled annual baseline CO_2 emissions	tCO_2

5.3.3 Estimating Abandonment Rates and Performance Decline

For this Dairy Digester Project Forecast Methodology, uncertainty related to project longevity (representing both abandonment rates and performance decline) during the full crediting period will be accounted for using a Project Longevity Adjustment Factor (U_{pl}), applied as a fraction of 0.95 to discount the calculation of forecast emission reductions (Equation 5.1). In addition to taking this discount, project proponents must provide adequate demonstration that all of the risk mitigation measures provided in Table 3.1 have been appropriately implemented, in order for the project to be eligible to generate FMUs. Appendix D provides expanded discussion for project longevity analyses and considerations for inclusion in this methodology.

5.4 Leakage Accounting

This methodology is not expected to cause the movement of dairy related emissions outside of the project area (termed 'leakage') as a result of project activities. Instead, the implementation of this activity in intended to provide sufficient financial incentive to achieve emission reduction goals, without causing dairies to move to parts of the country without such environmental regulations.

[23] Refer to the version of the United States EPA eGRID most closely corresponding to the time period of confirmation. Projects shall use the annual total output emission rates for the subregion where the project is located, not the annual non-baseload output emission rates. The eGRID tables are available from the EPA website: www.epa.gov/energy/emissions-generation-resource-integrated-database-egrid.

6 Project Implementation and Documentation

Climate Forward requires a Project Implementation Report to be established for all monitoring and reporting activities associated with the project. The Project Implementation Report will serve as the basis for the confirmation body to confirm that the monitoring and reporting requirements in this methodology have been met. The Project Implementation Report must cover all aspects of monitoring and reporting contained in this methodology and must specify how data for all relevant parameters will be collected and recorded.

At a minimum, the Project Implementation Report shall include the frequency of data acquisition, parameter values, a record keeping plan, and the role of individuals performing each specific monitoring activity. The Project Implementation Report must also include procedures that the project proponent has followed to ascertain and demonstrate that the project passes the legal requirement test and is in regulatory compliance.

Project proponents are responsible for ensuring that all monitoring and reporting requirements of this methodology have been met.

6.1 Quantification Parameters

Each project must include the prescribed monitoring parameters necessary to calculate baseline and project emissions. These must be shown in a table such as below in Table 6.1. The project proponent must provide the Reserve robust evidence demonstrating to the Reserve's satisfaction that proposed parameter values are reasonable and conservative. Confirmation bodies will confirm Reserve-approved parameter values are used in each project.

Table 6.1. Project Monitoring Parameters

Parameter	Description	Data Unit	Calculated (c) Measured (m) Reference(r) Operating Records (o)	Comment
ER	Forecasted GHG emission reductions	tCO_2e	c	
BE	Modeled baseline GHG emissions	tCO_2e	c	
PE	Forecasted project GHG emissions	tCO_2e	c	
Regulations	Project proponent attestation to compliance with regulatory requirements relating to the dairy digester project	All applicable regulations	n/a	Information used to demonstrate compliance with associated regulations and rules, e.g., criteria pollutant and effluent discharge limits
L	Type of livestock categories on the farm	Livestock categories	o	Select from list provided in Table B.2 and Table B.3

Parameter	Description	Data Unit	Calculated (c) Measured (m) Reference(r) Operating Records (o)	Comment
MS_S	Fraction of manure managed in the baseline waste handling system *S*	Percent (%)	o	Reflects the percent of waste handled by the system components *S* pre-project. Each system component must have an MS value per livestock category Within each livestock category, the sum of MS values (for all treatment/storage systems) equals 100%. Select from list provided in Table B.1
P_L	Average number of animals for each livestock category *L*	Population (# head)	o	
$Mass_L$	Average live weight by livestock category *L*	kg	o, r	From operating records, or if onsite data are unavailable, from lookup table (Table B.2 and Table B.4) *Confirmation body:* Confirm correct value from table used
T_{mo}	Average monthly temperature at location of the operation	°C	m/o	Used for van't Hoff calculation and for choosing appropriate MCF value. *Confirmation body:* Review temperature records obtained from weather service
$B_{0,L}$	Maximum methane producing capacity for manure by livestock category	(m^3 CH_4/kgVS)	r	From Table B.3 *Confirmation body:* Confirm correct value from table used
MCF	Methane conversion factor	Percent (%)	r	From Appendix B Differentiate by livestock category. *Confirmation body:* Confirm correct value from table used
VS_L	Daily volatile solid production for each livestock category *L*	(kg/animal/day)	r, c	Table B.2 and Table B.4 *Confirmation body:* Confirm correct value from table used
f	van't Hoff-Arrhenius factor	n/a	c	The proportion of volatile solids that are biologically available for conversion to methane based on the monthly temperature of the system
Y_{cp}	Number of years in crediting period	years	r	
U_{pl}	Project Longevity Adjustment Factor	fraction	r	Use value of 0.95
D_{CH4}	Density of methane	kg/m^3	r	Use value of 0.68
$C_{Mg/kg}$	Conversion factor, kg to Mg	Mg/kg	r	Use value of 1×10^{-3}
GWP_{CH4}	Global warming potential of methane	tCO_2e/tCH_4	r	As of this writing, the value shall be 25 (in accordance with the IPCC 4th Assessment Report, 2007), until updated guidance is issued by Climate Forward
AS	Anaerobic storage / treatment system	n/a	r	Select from list provided in Table B.1
m	Month in baseline calculation period	month	o	

Parameter	Description	Data Unit	Calculated (c) Measured (m) Reference(r) Operating Records (o)	Comment
VS_{avail}	Monthly volatile solids available for degradation in each anaerobic storage system, for each livestock category	kg dry matter	c, o	
$VS_{deg\ AS,L}$	Monthly volatile solids degraded in each anaerobic storage system *AS*, for each livestock category *L*	kg dry matter	c, o	
d_m	Number of days in each month	days	r	
MDP	Model calibration factor for management and design practices	fraction	r	Use value of 0.8[24]
E	Activation energy constant	cal/mol	r	Use value of 15,175
T_{max}	Temperature of maximum reaction rate constant	Kelvin	r	Use value of 303.16
T_{amb}	Monthly ambient temperature	Kelvin	o	
R	Ideal gas constant	cal/Kelvin·mol	r	Use value of 1,987
f_{max}	Maximum *f* factor	fraction	r	Use value of 0.95
$Q_{E,grid}$	Quantity of grid-connected electricity consumed for each emission source 'E' during the baseline calculation period	MWh	o	
EF_{grid}	eGrid emission factor for grid electricity consumed	tCO_2/MWh	r	
$Q_{F,fuel}$	Quantity of fossil fuel consumed for each mobile and stationary combustion source 'F' during the baseline calculation period	MMBtu or gal	o	Make sure data units are consistent across parameters in Equation 5.10
EF_{fuel}	Fuel specific emission factor	$kgCO_2$/ MMBtu or gal	r	Use default values from Table B.8
BCE	Biogas capture efficiency of the anaerobic digester, accounts for gas leaks	Fraction	r	Use default value Appendix B
$BDE_{BCS,m}$	Forecast overall monthly methane destruction efficiency of the BCS	fraction	c	As quantified in Equation 5.15

[24] Mangino, et al. This factor was derived to "account for management and design practices that result in the loss of volatile solids from the management system." This reflects the difference between the theoretical modeled biological activity and empirical measurement of biological activity due to removal of liquid or other management practices that result in loss of VS from the treatment system. This does not account for removal of solids prior to the treatment system.

Parameter	Description	Data Unit	Calculated (c) Measured (m) Reference(r) Operating Records (o)	Comment
$BCS_{CH4,vent,m}$	Forecast annual quantity of methane vented to the atmosphere due to venting events	tCH_4	c	As quantified in Equation 5.16
$FP_{DD,m}$	Forecast monthly percentage of total biogas flow to destruction device "DD"	fraction	o	
V_f	Methane Venting Factor	fraction		Site specific value must be set based on available historical data, manufacturer guidance, published literature, or similar source, and must be approved by Climate Forward prior to confirmation
$VS_{ETAS,L,m}$	Forecast volatile solid input to effluent treatment system 'ET' for livestock category 'L'	Kg dry matter/day	c	
ETF_{ET}	Fraction of effluent that exits the digester and is input directly to the effluent treatment system 'ET'	fraction	c	
d_p	Number of days in the forecast period	days	o	

6.2 Voluntary Ongoing Monitoring Incentive

Each Climate Forward methodology is designed to ensure the quantification of emission reductions over the crediting period is conservative. It may be possible to have additional FMUs issued following *ex post* verification, using data collected by the project through ongoing monitoring of parameters relevant to the quantification methodology. For this methodology, *ex ante* risk related to project abandonment and performance decline during the full crediting period is accounted for through the application of the Project Longevity Adjustment Factor (U_{pl}). This factor, valued at 0.95 for all projects, discounts the calculation of forecast emission reductions (Equation 5.1).

In order to conduct a successful *ex post* project verification, and generate additional FMUs from the dairy project, the project proponent shall conduct ongoing monitoring of all relevant project parameters. This methodology does not currently prescribe detailed monitoring and metering or QA/QC procedures, but it is strongly recommended that the project follow an approach as close as possible to that required by the most current version of the Reserve's U.S. Livestock Project Protocol.[25]

[25] Current and previous versions of the Reserve's U.S. Livestock Project Protocol, as well as supporting documents and information, are available online at: http://www.climateactionreserve.org/how/protocols/us-livestock/. As of this writing, the Reserve also makes available an Excel-based calculation tool for livestock projects.

7 Reporting and Record Keeping

This section provides requirements and guidance on reporting rules and procedures. A priority of Climate Forward is to facilitate consistent and transparent information disclosure among project proponents. Project proponents must submit an emission reduction report as part of the Project Implementation Report to Climate Forward.

7.1 Project Submittal and Confirmation Documentation

The following documents are required for project listing and confirmation with Climate Forward:

- Project Submission form
- Signed Attestation of Title form
- Signed Attestation of Legal Additionality form
- Signed Attestation of Regulatory Compliance form
- Project Implementation Report
- Confirmation Report
- Confirmation Statement

At a minimum, the above project documentation will be available to the public via the Climate Forward online registry. Further disclosure and other documentation may be made available on a voluntary basis through the Climate Forward registry. [26]

7.2 Record Keeping

For purposes of independent confirmation and historical documentation, project proponents are required to keep all information outlined in this methodology for a period equal to either the project crediting period or seven years after the information is generated, whichever is greater. This information will not be publicly available, but may be requested by the confirmation body or the Reserve. Records must be kept in both hard copy and digital format, where possible.

Examples of information the project proponent must retain includes:

- All data inputs for the calculation of the project emission reductions, including all required sampled data
- Copies of all permits, formal notices of regulatory violations, and any relevant administrative or legal consent orders dating back at least 3 years prior to the implementation of the first project device
- Executed Attestation of Title, Attestation of Regulatory Compliance, and Attestation of Legal Additionality forms
- Results of emission reduction calculations
- Confirmation records and results
- All evidence relating to Continued Implementation

Climate Forward also requires that the following project-related records be retained by the confirmation body for a period equal to either the project crediting period or seven years after the completion of confirmation activities, whichever is greater. It must be noted that some records may be subject to fiscal or other legal requirements that are longer than Climate Forward's mandated period.

[26] Climate Forward documents and forms are available at https://climateforward.org/program/program-and-project-forms/

Confirmation bodies shall retain electronic copies, as applicable, of:

- The project's Project Implementation Report
- The project proponent's SSR and/or project activity data as well as evidence cited
- The confirmation plan
- The sampling plan
- The Confirmation Report
- The List of Findings
- The Confirmation Statement

Each confirmation body must have an easily accessible record-keeping system, preferably electronic, that provides readily available access to project information. Copies of the original activity and source data records shall be maintained within said record-keeping system. Records must be kept in both hard copy and digital format, where possible. The Reserve may at any time request access to the record-keeping system or any supporting documentation for oversight or auditing purposes.

7.3 Reporting and Confirmation Period

Project proponents must report forecasted GHG reductions from the project for the entire crediting period. A confirmation period is the period of time over which forecasted GHG reductions are confirmed. The confirmation period is the period of time beginning with the project start date and ending with the submission of the final Confirmation Report to Climate Forward. The end date of any confirmation period may not extend past the project crediting end date.

Confirmation activities cannot commence until the project is submitted by the project proponent and approved by the Reserve, and at least three months following the project start date. Confirmation must conclude, and a Confirmation Statement must be issued, no later than two years after the project start date, except for in cases of greenfield projects, which require confirmation conclusion and Confirmation Statement issuance no later than three calendar years after the project start date. Successful confirmation fixes the start and ends dates of the project crediting period for the duration of the project.

7.3.1 Expansion Project Confirmations

Expansion project confirmation activities cannot commence until the expansion project is submitted and approved by the Reserve. Confirmation must conclude, and a Confirmation Statement must be issued, no later than two years after expansion completion, as defined in Section 3. The confirmation period for a project expansion starts when the expansion is completed; the confirmation period end date is not permitted to extend past the project crediting end date confirmed and fixed during project confirmation. There is no limit to the number of expansion confirmations that may be conducted throughout the established project crediting period. A site visit is required during any expansion confirmation, including confirmation of Project Resilience Measures.

7.4 *Ex Post* Verification

Ex post issuance may be possible for dairy projects if data from each year of the crediting period are submitted in a Project Monitoring Report and verified at the conclusion of the crediting period. A site visit is required during an *ex post* verification. This methodology does not currently prescribe detailed *ex post* verification procedures, but it is strongly recommended that the verifier follow an approach as close as possible to that required by the most current version of the Reserve's U.S. Livestock Project Protocol.[27]

[27] Current and previous versions of the Reserve's Livestock Project Protocol, as well as supporting documents and information, are available online at: http://www.climateactionreserve.org/how/protocols/us-livestock/.

8 Confirmation Guidance

This section provides confirmation bodies with guidance on confirming GHG emission reductions associated with the project activity. This confirmation guidance supplements the Climate Forward Confirmation Manual and describes confirmation activities specifically related to this methodology.

Confirmation bodies trained to confirm a given methodology type must be familiar with the following documents:

- Climate Forward Program Manual
- Climate Forward Confirmation Manual
- Dairy Digester Project Forecast Methodology (this document)

The Climate Forward Program Manual, Climate Forward Confirmation Manual, and Climate Forward methodologies are designed to be compatible with each other and are posted on the Climate Forward website at http://www.climateforward.org.

Only confirmation bodies trained and accredited by the Reserve are eligible to confirm project reports. Information about confirmation body accreditation and Climate Forward project confirmation training can be found on the Climate Forward website at http://www.climateforward.org/program/confirmation/.

8.1 Standard of Confirmation

While there is no requirement for *ex post* verification of this project under Climate Forward, there is a requirement for an accredited confirmation body to confirm the project has been implemented as described in the forecast methodology and that the estimated emission reductions or removals have been calculated accurately. The confirmation incorporates both a desktop documentation review and a site visit assessment of the mitigation project.

Beyond criteria for the confirmation of mitigation project implementation, the confirmation body also confirms any provisions specified in the forecast methodology that are to be undertaken to ensure the continued implementation of the mitigation project for the duration of its crediting period. The confirmation body assesses whether such measures have been appropriately implemented.

8.2 Project Implementation Report

The Project Implementation Report serves as the basis for confirmation bodies to confirm that the monitoring and reporting requirements have been met. Confirmation bodies shall confirm that the Project Implementation Report covers all aspects of monitoring and reporting contained in this methodology and specifies how data for all relevant parameters were collected and recorded.

When assessing the Project Implementation Report, the confirmation body shall:

(a) Assess the compliance of the Project Implementation Report with the requirements of the methodology, Climate Forward Program Manual, and Climate Forward Confirmation Manual;

(b) Identify the list of parameters required by the methodology and confirm that the Project Implementation Report accounted for all necessary parameters;

(c) Assess the means of implementation of the project data capture, including data management and quality assurance and quality control procedures, and determine whether these are sufficient to ensure the accuracy of forecasted GHG emission reductions to be achieved by the project.

Where the project proponent has applied a sampling approach to determine data and parameters, the confirmation body shall assess the proposed sampling plan in accordance with sampling requirements in section 4.3.3 of ISO 14064-3.

8.3 Core Confirmation Activities

The Climate Forward Confirmation Manual describes the core confirmation activities that shall be performed by confirmation bodies for all project confirmations.

Confirmation is a risk assessment and data sampling effort designed to ensure that the risk of reporting error is assessed and addressed through appropriate sampling, testing, and review. The core confirmation activities are:

1. Reviewing GHG management systems and estimation methodologies
2. Confirming emission reduction estimates
3. Undertaking site visits
4. Confirming implementation of project resilience measures

8.3.1 Reviewing GHG Management Systems and Estimation Methodologies

The confirmation body reviews and assesses the appropriateness of the methodologies and management systems that the project proponent uses to gather data and calculate baseline and project emissions.

8.3.2 Confirming Emission Reduction Estimates

The confirmation body further investigates areas that have the greatest potential for material misstatements and then confirms whether material misstatements have occurred. Include confirmation activities required to confirm emission reduction estimates such as independent recalculation.

8.3.3 Undertaking Site Visits

In addition to undertaking a desk review, confirmation bodies shall conduct one or more site visits. The specific itinerary for a site visit and the activities to be confirmed will be determined by the confirmation body, following an assessment of project risk. A site visit shall be used to confirm the GHG Assessment Boundary, examine project equipment, identify any associated SSRs resulting from the project, and assess the implementation and operation of the project activity. Furthermore, confirmation bodies must confirm the project crediting period adequately represents project life expectancy as outlined in Section 3. At a minimum, the implementation of Project Resilience Measures must be confirmed during site visits (where practical). Site visits are also required for *ex post* verification (see Section 6.2), and the confirmation of expansion activities (see Section 7.3.1).

8.3.4 Confirming Implementation of Project Resilience Measures

The confirmation body reviews and assesses evidence provided to demonstrate each of the project resilience measures outlined in Section 3.7 and Table 3.1 have been appropriately implemented.

8.4 Confirmation Items

The confirmation body needs to address a set of items for each methodology type. This can be displayed in a table that lists the item, references the section in the methodology where requirements are specified, and identifies if professional judgment needs to be applied during the confirmation activity.

Confirmation bodies are expected to use their professional judgment to confirm that methodology requirements have been met in instances where the methodology does not provide sufficiently prescriptive guidance. For more information on Climate Forward's confirmation process and professional judgment, please see the Climate Forward Confirmation Manual.

Note: The tables below shall not be viewed as a comprehensive list or plan for confirmation activities, but rather guidance on areas specific to livestock projects that must be addressed during confirmation.

8.4.1 Project Eligibility and Credit Issuance

Table 8.1 lists the criteria for reasonable assurance with respect to eligibility and credit issuance for dairy manure digestion projects. These requirements determine if a project is eligible to register with Climate Forward and/or have credits issued. If any requirement is not met, the project may be determined ineligible.

Table 8.1. Eligibility Confirmation Items

Methodology Section	Eligibility Qualification Item	Apply Professional Judgment?
3.1	Location – confirm projects are located in the United States and its territories, or on U.S. tribal lands	No
3.2	Project start date – confirm the start date is appropriately chosen and that the project was submitted to Climate Forward within two calendar years of the project start date	Yes
3.2	Crediting period – confirm the crediting period is appropriate vis-à-vis the chosen digester technology	No
3.3.1	Additionality – performance standard test – confirm the project installed a biogas destruction system	No
3.3.2	Additionality – legal requirement test – confirm the project was not mandated by any laws – confirm the project was submitted to the Program with a start date prior to any relevant laws being adopted – confirm the project was registered / listed prior to the date any relevant law was adopted and that the start date is before the date on which such laws become effective	No
3.3.3	Additionality – uncontrolled anaerobic baseline – confirm manure was treated anaerobically before the project. Confirm baseline manure management system had sufficient depth to be considered anaerobic. For pre-existing dairies, confirm anaerobic manure treatment system	Yes

Methodology Section	Eligibility Qualification Item	Apply Professional Judgment?
	was in place prior to start date. For new dairy facilities, confirm there are no restrictions on the construction of uncontrolled anaerobic manure treatment systems in the industry and geographic region of the mitigation project. For expansions of existing projects, confirm that additional BCS storage capacity exceeds requisite capacity for the expanded herd size, and that the expansion in capacity meets or exceeds 15% of the baseline herd capacity, and herd capacity has stabilized for at least 12 months prior to commencement of confirmation activities	
3.4	Environmental and social safeguards – confirm the project is not expected to cause adverse environmental, social or economic impacts. Confirm appropriate mitigation measures are in place to guard against such risks	Yes
3.5	Confirm no laws have been broken in the implementation of the project	No
3.6	Confirm no other GHG mitigation credits have been issued for the project, during the crediting period	No
3.7	Confirm Project Resilience Measures have been implemented as described, including during site visit	Yes

8.4.2 Quantification

Table 8.2 lists the items that confirmation bodies shall include in their risk assessment and recalculation of the project's GHG emission reductions. These quantification items inform any determination as to whether there are material and/or immaterial misstatements in the project's GHG emission reduction calculations. If there are material misstatements, the calculations must be revised before FMUs are issued.

Table 8.2. Quantification Confirmation Items

Methodology Section	Quantification Item	Apply Professional Judgment?
4	Confirm that all SSRs in the GHG Assessment Boundary are accounted for	No
5.1	Confirm project longevity adjustment factor applied correctly	No
5.2	Confirm the livestock categories are correct differentiated	Yes
5.2	Confirm the project proponent applied the correct VS and B_0 values for each livestock category	No
5.2	Confirm the fraction of manure handled in different manure management system components is satisfactorily represented	*Yes*
5.2	Confirm the project proponent used methane conversion factors differentiated by temperature	No
5.2	Confirm the methane baseline emissions calculations for each livestock category were calculated according to the methodology with appropriate data	No
5.2	Confirm the project proponent correctly aggregated methane emissions from sources within each livestock category	No
5.2.3 5.3.2	Confirm that the project proponent correctly monitored, quantified and aggregated electricity use	No
5.2.3 5.3.2	Confirm that the project proponent correctly monitored, quantified and aggregated fossil fuel use	No

Methodology Section	Quantification Item	Apply Professional Judgment?
5.2.3 5.3.2	Confirm that the project proponent applied the correct emission factors for fossil fuel combustion and grid-delivered electricity	No
5.3	Confirm that the project emissions calculations were calculated according to the methodology with the appropriate data	No
5.3.1.1	Confirm that the project proponent applied the correct methane destruction efficiencies	No
5.3.1.1	Confirm that the project proponent correctly quantified the amount of uncombusted methane	No
5.3.1.1	Confirm that methane emissions resulting from venting are estimated correctly	Yes
5.3.1.2	Confirm that the project proponent applied the correct B_0 value for Modeled Project Methane Emissions from Anaerobic Treatment of BCS Effluent	No

In assessing the appropriateness of parameter values, the confirmation body shall*:*

a) Confirm approval was given by the Reserve for use of such values.

b) Determine whether all *ex ante* data sources and assumptions are appropriate and calculations are correct as applicable under the methodology and results in an accurate and conservative estimate of the forecasted emission reductions.

c) Determine whether all *ex post* data sources and assumptions are appropriate and calculations are correct. Whether these data, with respect to specific parameters defined, are replicable to a reasonable and logical extent.

8.4.3 Risk Assessment

Confirmation bodies will review the following items in Table 8.3 to guide and prioritize their assessment of data used in determining eligibility and quantifying GHG emission reductions.

Table 8.3. Risk Assessment Confirmation Items

Methodology Section	Item that Informs Risk Assessment	Apply Professional Judgment?
6	Confirm that the project Monitoring Plan is sufficiently rigorous to support the requirements of the methodology and proper operation of the project	Yes
6	Confirm that the BCS was operated and maintained according to manufacturer specifications	No
6	Confirm that the individual or team responsible for managing and reporting project activities are qualified to perform this function	Yes
6	Confirm that appropriate training was provided to personnel assigned to greenhouse gas reporting duties	Yes
6	Confirm that all contractors are qualified for managing and reporting greenhouse gas emissions if relied upon by the project developer. Confirm that there is internal oversight to assure the quality of the contractor's work	Yes
7.2	Confirm that all required records have been retained by the project proponent	No

8.5 Completing Confirmation

The Climate Forward Confirmation Manual provides detailed information and instructions for confirmation bodies to finalize the confirmation process. It describes completing a Confirmation Report, preparing a Confirmation Statement, submitting the necessary documents to Climate Forward, and notifying the Reserve of the project's confirmed status.

9 Glossary of Terms

Accredited confirmation body	A confirmation firm approved by the Reserve to provide confirmation services for project proponents.
Additionality	Project activities that are above and beyond "business as usual" operation, exceed the baseline characterization, and are not mandated by regulation.
Anthropogenic emissions	GHG emissions resultant from human activity that are considered to be an unnatural component of the Carbon Cycle (i.e., fossil fuel destruction, de-forestation, etc.).
Biogenic CO_2 emissions	CO_2 emissions resulting from the destruction and/or aerobic decomposition of organic matter. Biogenic emissions are considered to be a natural part of the Carbon Cycle, as opposed to anthropogenic emissions.
Carbon dioxide (CO_2)	The most common of the six primary greenhouse gases, consisting of a single carbon atom and two oxygen atoms.
CO_2 equivalent (CO_2e)	The quantity of a given GHG multiplied by its total global warming potential. This is the standard unit for comparing the degree of warming which can be caused by different GHGs.
Confirmation	The process used to ensure that a given participant's GHG emissions or emission reductions have met the minimum quality standard and complied with Climate Forward's procedures and methodologies for calculating and reporting GHG emissions and emission reductions.
Confirmation body	An organization or company that has been ISO-accredited and approved by the Reserve to perform GHG confirmation activities for specific forecast methodologies.
Direct emissions	GHG emissions from sources that are owned or controlled by the reporting entity.
Emission factor (EF)	A unique value for determining an amount of a GHG emitted for a given quantity of activity data (e.g., metric tons of carbon dioxide emitted per barrel of fossil fuel burned).
Fossil fuel	A fuel, such as coal, oil, and natural gas, produced by the decomposition of ancient (fossilized) plants and animals.
Greenhouse gas (GHG)	Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulfur hexafluoride (SF_6), hydrofluorocarbons (HFCs), or perfluorocarbons (PFCs).
GHG reservoir	A physical unit or component of the biosphere, geosphere, or hydrosphere with the capability to store or accumulate a GHG that has been removed from the atmosphere by a GHG sink or a GHG captured from a GHG source.
GHG sink	A physical unit or process that removes GHG from the atmosphere.
GHG source	A physical unit or process that releases GHG into the atmosphere.

Global Warming Potential (GWP)	The ratio of radiative forcing (degree of warming to the atmosphere) that would result from the emission of one unit of a given GHG compared to one unit of CO_2.
Indirect emissions	Reductions in GHG emissions that occur at a location other than where the reduction activity is implemented, and/or at sources not owned or controlled by project participants.
Metric ton (t, tonne)	A common international measurement for the quantity of GHG emissions, equivalent to about 2204.6 pounds or 1.1 short tons.
Project baseline	A "business as usual" GHG emission assessment against which GHG emission reductions from a specific GHG reduction activity are measured.
Project Implementation Report	A report prepared by the project proponent containing all data, calculations, and information necessary for the confirmation of the ICS project and the issuance of *ex ante* FMUs.
Project Monitoring Report	A report prepared by the project proponent containing all monitoring data, calculations, and information necessary for the *ex post* verification of the ICS project and the issuance of additional FMUs
Project proponent	An entity that undertakes a GHG project, as identified in Section 2.1 of this methodology.
Project Resilience Measures	Activities tailored to the specific project that are undertaken to ensure the continuing implementation of the project for the duration of the crediting period.

10 References

Climate Action Reserve's U.S. Livestock Project Protocol Version 4.0 (January 23, 2013)

Climate Forward Program Manual

Climate Forward Confirmation Manual

International Organization for Standardization, ISO 14064-2:2006 Greenhouse gases — Part 2: Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements (2006).

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

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

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

United Nations Framework Convention on Climate Change (UNFCCC) Clean Development Mechanism (CDM) methodology ACM00010 (available at: http://cdm.unfccc.int/methodologies/PAmethodologies/approved.html).

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

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

U.S. Environmental Protection Agency – Climate Leaders Offset Methodology for Managing Manure with Biogas Recovery Systems V.1.3 (2008).

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

Appendix A Associated Environmental Impacts

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

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

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

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

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

Appendix B Emission Factor Tables

Table B.1. Manure Management System Components

System	Definition
Pasture/Range/ Paddock	The manure from pasture and range grazing animals is allowed to lie as deposited and is not managed.
Daily spread	Manure is routinely removed from a confinement facility and is applied to cropland or pasture within 24 hours of excretion.
Solid storage	The storage of manure, typically for a period of several months, in unconfined piles or stacks. Manure is able to be stacked due to the presence of a sufficient amount of bedding material or loss of moisture by evaporation.
Dry lot	A paved or unpaved open confinement area without any significant vegetative cover where accumulating manure may be removed periodically.
Liquid/Slurry	Manure is stored as excreted or with some minimal addition of water in either tanks or earthen ponds outside the animal housing, usually for periods less than one year. Per IPCC Guidelines, if manure contains less than 20% dry matter it can be considered liquid.
Uncovered anaerobic lagoon	A type of liquid storage system designed and operated to combine waste stabilization and storage. Lagoon supernatant is usually used to remove manure from the associated confinement facilities to the lagoon. Anaerobic lagoons are designed with varying lengths of storage (up to a year or greater), depending on the climate region, the volatile solids loading rate, and other operational factors. The water from the lagoon may be recycled as flush water or used to irrigate and fertilize fields.
Pit storage below animal confinements	Collection and storage of manure usually with little or no added water typically below a slatted floor in an enclosed animal confinement facility, usually for periods less than one year.
Anaerobic digester	Animal excreta with or without straw are collected and anaerobically digested in a large containment vessel or covered lagoon. Digesters are designed and operated for waste stabilization by the microbial reduction of complex organic compounds to CO_2 and CH_4, which is captured and flared or used as a fuel.
Burned for fuel	The dung and urine are excreted on fields. The sun-dried dung cakes are burned for fuel.
Cattle and Swine deep bedding	As manure accumulates, bedding is continually added to absorb moisture over a production cycle and possibly for as long as 6 to 12 months. This manure management system also is known as a bedded pack manure management system and may be combined with a dry lot or pasture.
Composting – In-vessel*	Composting, typically in an enclosed channel, with forced aeration and continuous mixing.
Composting – Static pile*	Composting in piles with forced aeration but no mixing.
Composting – Intensive windrow*	Composting in windrows with regular (at least daily) turning for mixing and aeration.
Composting – Passive windrow*	Composting in windrows with infrequent turning for mixing and aeration.

System	Definition
Aerobic treatment	The biological oxidation of manure collected as a liquid with either forced or natural aeration. Natural aeration is limited to aerobic and facultative ponds and wetland systems and is due primarily to photosynthesis. Hence, these systems typically become anoxic during periods without sunlight.

*Composting is the biological oxidation of a solid waste including manure usually with bedding or another organic carbon source typically at thermophilic temperatures produced by microbial heat production.
Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Chapter 10: Emissions from Livestock and Manure Management, Table 10.18: Definitions of Manure Management Systems, p. 10.49.

Table B.2. Livestock Categories and Typical Animal Mass

Livestock Category (L)	Livestock Typical Animal Mass (TAM)
Dairy cows (on feed)	680[b]
Non-milking dairy cows (on feed)	684[a]
Heifers (on feed)	407[b]
Bulls (grazing)	750[b]
Calves (grazing)	118[b]
Heifers (grazing)	351[b]
Cows (grazing)	582.5[b]

Sources for TAM:
a. American Society of Agricultural Engineers (ASAE) Standards 2005, ASAE D384.2.
b. Environmental Protection Agency (EPA), Inventory of U.S. GHG Emissions and Sinks 1990-2010 (2012), Annex 3, Table A-191, pg. A-246.

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

Livestock Category (L)	VS_L (kg/Mg animal mass x·day)	$B_{0,L}$ [b] (m^3 CH_4/kg VS added)
Dairy cows	See Appendix B, Table B.5	0.24
Non-milking dairy cows	5.56	0.24
Heifers	See Appendix B, Table B.5	0.17
Bulls (grazing)	6.04[b]	0.17
Calves (grazing)	6.41[b]	0.17
Heifers (grazing)	See Appendix B, Table B.5	0.17
Cows (grazing)	See Appendix B, Table B.5	0.17

a. American Society of Agricultural Engineers (ASAE) Standards 2005, ASAE D384.2, VS_L(kg/day per animal) from table 1.b (p.2) converted to (kg/day/1000 kg mass) using average Live Weight (kg)values from table 5c (p.7).
b. Environmental Protection Agency (EPA) – Climate Leaders Draft Manure Offset Protocol, October 2006, Table IIa: Animal Waste Characteristics (VS, B_0, and N_{ex} rates), p. 18.

Table B.4. Biogas Collection Efficiency by Digester Type

Digester Type	Cover Type	Biogas Collection Efficiency
Covered Anaerobic Lagoon	Bank-to-Bank, impermeable	0.95
	Partial area (modular), impermeable	(0.95) × (% area covered)
Complete mix, plug flow, or fixed film digester	Enclosed vessel	0.98
Two stages of differing types	With flow metered for each stage	$\frac{(BCE_1 \times EstFlow_1) + (BCE_2 \times EstFlow_2)}{Total\ estimated\ biogas\ flow}$
	No separate flow metering	$(BCE_1 \times 0.7) + (BCE_2 \times 0.3)$

Adapted from: U.S. EPA Climate Leaders, Offset Project Methodology for Managing Manure and Biogas Recovery Systems, 2008. Table IIf (original table has been expanded upon).

Table B.5. 2010 Volatile Solid Default Values for Livestock Category Types (kg/Mg animal mass day)

State	VS Dairy Cow	VS Heifer	VS Heifer-Grazing	VS Cows- Grazing
Alabama	8.99	8.43	8.53	7.82
Alaska	7.98	8.43	9.98	8.89
Arizona	11.47	8.43	9.77	8.89
Arkansas	8.3	8.43	8.48	7.82
California	11.27	8.43	9.48	8.89
Colorado	11.54	8.43	9.27	8.89
Connecticut	10.22	8.43	8.62	7.87
Delaware	9.53	8.43	8.53	7.87
Florida	10.26	8.43	8.63	7.82
Georgia	10.03	8.43	8.49	7.82
Hawaii	8.43	8.43	9.77	8.89
Idaho	11.24	8.43	9.41	8.89
Illinois	10.19	8.43	7.78	7.47
Indiana	10.54	8.43	7.91	7.47
Iowa	10.67	8.43	7.64	7.47
Kansas	10.74	8.43	7.61	7.47
Kentucky	9.11	8.43	8.4	7.82
Louisiana	7.98	8.43	8.63	7.82
Maine	9.94	8.43	8.51	7.87
Maryland	10	8.43	8.51	7.87
Massachusetts	9.67	8.43	8.53	7.87
Michigan	11.42	8.43	7.83	7.47
Minnesota	10.25	8.43	7.83	7.47
Mississippi	8.59	8.43	8.53	7.82
Missouri	8.81	8.43	7.97	7.47
Montana	10.63	8.43	8.42	7.82
Nebraska	10.38	8.43	9.25	8.89
Nevada	11.08	8.43	8.01	7.47
New Hampshire	10.4	8.43	9.62	8.89
New Jersey	9.69	8.43	8.45	7.87
New Mexico	11.81	8.43	8.43	7.87
New York	10.69	8.43	9.5	8.89
North Carolina	10.54	8.43	8.61	7.87
North Dakota	9.92	8.43	8.31	7.82
Ohio	10.27	8.43	7.95	7.47
Oklahoma	9.59	8.43	7.9	7.47
Oregon	10.54	8.43	8.33	7.82
Pennsylvania	10.39	8.43	9.56	8.89
Rhode Island	9.76	8.43	8.66	7.87
South Carolina	10.02	8.43	8.61	7.87
South Dakota	10.59	8.43	8.19	7.82
Tennessee	9.56	8.43	8.12	7.47
Texas	10.87	8.43	8.21	7.82
Utah	10.86	8.43	8.42	7.82
Vermont	10	8.43	9.56	8.89
Virginia	10.09	8.43	8.52	7.87
Washington	11.5	8.43	8.25	7.82
West Virginia	9.15	8.43	9.73	8.89
Wisconsin	10.63	8.43	7.96	7.47
Wyoming	10.46	8.43	9.62	8.89

Source: Environmental Protection Agency (EPA). U.S. Inventory of GHG Sources and Sinks 1990-2010 (2012), Annex 3, Table A-192, page A-237.

Table B.6. IPCC 2006 Methane Conversion Factors by Manure Management System Component / Methane Source

MCF Values by Temperature for Manure Management Systems																				
	Average annual temperature (°C)																			
	Cool					Temperate											Warm			
System[a]	<10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	>28	Source and comments
Pasture/Range/Paddock	0.010					0.015											0.020			Judgment of IPCC Expert Group in combination with Hashimoto and Steed (1994).
Daily spread	0.00					0.005											0.010			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	0.010					0.015											0.020			Judgment of IPCC Expert Group in combination with Hashimoto and Steed (1994).
Liquid/slurry w/natural crust cover[40]	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 dependent on temperature, rainfall, and composition.
Liquid/slurry uncovered	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	0.80	Judgment of IPCC Expert Group in combination with Mangino et al. (2001).
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
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 he ambient temperature, not the stable temperature is to be used for determining the climatic conditions.
Pit storage below animal confinements (>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	0.80	Judgment of IPCC Expert Group in combination with Mangino et al. (2001). Note that the ambient temperature, not the stable temperature is to be used for determining the climatic conditions.
Anaerobic digester	0 - 1					0 - 1											0 - 1			Should be subdivided in different categories, considering amount of recovery of the biogas, flaring of the biogas and storage after digestion. Calculation
Burned for fuel	0.10					0.10											0.10			Judgment of IPCC Expert Group in combination with Safley et al. (1992).

MCF Values by Temperature for Manure Management Systems																				
	Average annual temperature (°C)																			
	Cool					Temperate											Warm			
System[a]	**<10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**>28**	**Source and comments**
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 (>1	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 or aerated static pile[b]	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 - passive or intensive windrow[b]	0.005					0.010											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

[a] Definitions for manure management systems are provided in Table B.1.

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

Adapted from 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Chapter 10: Emissions from Livestock and Manure Management, Table 10.17. MCF values shall be chosen based on the average temperature at the site for an entire calendar year, even if the reporting period does not exactly cover a calendar year.

A "natural crust cover" is a naturally-forming layer that covers the majority of the liquid surface at a thickness sufficient to support communities of oxidizing bacteria, and which persists throughout the year. Evidence of such a cover (including the area covered, thickness, and persistence) must be provided by the project developer during confirmation in order to justify the use of this MCF value.

Table B.7. Biogas Destruction Efficiency Default Values by Destruction Device

If available, the official source tested methane destruction efficiency shall be used in place of the default methane destruction efficiency. Otherwise, project developers have the option to use either the default methane destruction efficiencies provided, or the site-specific methane destruction efficiencies, for each of the combustion devices used in the project case performed on an annual basis. Site-specific values must be provided by an independent air emissions testing body that is accredited by a state or local regulatory agency, or the Stack Testing Accreditation Council. Where a state/region does not have an appropriate accreditation system or accredited service providers, the project developer may look to another state/region to find suitably qualified service providers.

Biogas Destruction Device	Biogas Destruction Efficiency (BDE)[1]
Open Flare	0.96[2]
Enclosed Flare	0.995[2]
Lean-burn Internal Combustion Engine	0.936[2]
Rich-burn Internal Combustion Engine	0.995[2]
Boiler	0.98[2]
Microturbine or large gas turbine	0.995[2]
Upgrade and use of gas as CNG/LNG fuel	0.95[2]
Upgrade and injection into natural gas transmission and distribution pipeline	0.98[3]
Direct pipeline to an end-user	Per corresponding destruction device

Source:
1 Seebold, J.G., et al., Reaction Efficiency of Industrial Flares, 2003
2 The default destruction efficiencies for this source are based on a preliminary set of actual source test data provided by the Bay Area Air Quality Management District. The default destruction efficiency values are the lesser of the twenty fifth percentile of the data provided or 0.995. These default destruction efficiencies may be updated as more source test data are made available to the Reserve.
3 The Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories gives a standard value for the fraction of carbon oxidized for gas destroyed of 99.5% (Reference Manual, Table 1.6, page 1.29). It also gives a value for emissions from processing, transmission and distribution of gas which would be a very conservative estimate for losses in the pipeline and for leakage at the end user (Reference Manual, Table 1.58, page 1.121). These emissions are given as 118,000kgCH_4/PJ on the basis of gas consumption, which is 0.6%. Leakage in the residential and commercial sectors is stated to be 0 to 87,000kgCH_4/PJ, which equates to 0.4%, and in industrial plants and power station the losses are 0 to 175,000kg/CH_4/PJ, which is 0.8%. These leakage estimates are compounded and multiplied. The methane destruction efficiency for landfill gas injected into the natural gas transmission and distribution system can now be calculated as the product of these three efficiency factors, giving a total efficiency of (99.5% x 99.4% x 99.6%) 98.5% for residential and commercial sector users, and (99.5% x 99.4% x 99.2%) 98.1% for industrial plants and power stations. [Source: GE AES Greenhouse Gas Services, Landfill Gas Methodology, Version 1.0 (July 2007)]

Table B.8. CO_2 Emission Factors for Fossil Fuel Use

Fuel Type	Heat Content	Carbon Content (Per Unit Energy)	Fraction Oxidized	CO_2 Emission Factor (Per Unit Energy)	CO_2 Emission Factor (Per Unit Mass or Volume)
Coal and Coke	**MMBTU / Short ton**	**kg C / MMBTU**		**kg CO_2 / MMBTU**	**kg CO_2 / Short ton**
Anthracite Coal	25.09	28.26	1.00	103.62	2,599.83
Bituminous Coal	24.93	25.49	1.00	93.46	2,330.04
Sub-bituminous Coal	17.25	26.48	1.00	97.09	1,674.86
Lignite	14.21	26.30	1.00	96.43	1,370.32
Unspecified (Residential/	22.05	26.00	1.00	95.33	2,102.29
Unspecified (Industrial Coking)	26.27	25.56	1.00	93.72	2,462.12
Unspecified (Other Industrial)	22.05	25.63	1.00	93.98	2,072.19
Unspecified (Electric Utility)	19.95	25.76	1.00	94.45	1,884.53
Coke	24.80	31.00	1.00	113.67	2,818.93
Natural Gas (By Heat Content)	**BTU / Standard ft^3**	**kg C / MMBTU**		**kg CO_2 / MMBTU**	**kg CO_2 /**
975 to 1,000 Btu / Standard ft^3	975 – 1,000	14.73	1.00	54.01	Varies
1,000 to 1,025 Btu / Standard ft^3	1,000 – 1,025	14.43	1.00	52.91	Varies
1,025 to 1,050 Btu / Standard ft^3	1,025 – 1,050	14.47	1.00	53.06	Varies
1,050 to 1,075 Btu / Standard ft^3	1,050 – 1,075	14.58	1.00	53.46	Varies
1,075 to 1,100 Btu / Standard ft^3	1,075 – 1,100	14.65	1.00	53.72	Varies
Greater than 1,100 Btu / Standard	> 1,100	14.92	1.00	54.71	Varies
Weighted U.S. Average	1,029	14.47	1.00	53.06	0.0546
Petroleum Products	**MMBTU / Barrel**	**kg C / MMBTU**		**kg CO_2 /**	**kg CO_2 / gallon**
Asphalt & Road Oil	6.636	20.62	1.00	75.61	11.95
Aviation Gasoline	5.048	18.87	1.00	69.19	8.32
Distillate Fuel Oil (#1, 2, and 4)	5.825	19.95	1.00	73.15	10.15
Jet Fuel	5.670	19.33	1.00	70.88	9.57
Kerosene	5.670	19.72	1.00	72.31	9.76
LPG (average for fuel use)	3.849	17.23	1.00	63.16	5.79
Propane	3.824	17.20	1.00	63.07	5.74
Ethane	2.916	16.25	1.00	59.58	4.14
Isobutene	4.162	17.75	1.00	65.08	6.45
n-Butane	4.328	17.72	1.00	64.97	6.70
Lubricants	6.065	20.24	1.00	74.21	10.72
Motor Gasoline	5.218	19.33	1.00	70.88	8.81
Residual Fuel Oil (#5 and 6)	6.287	21.49	1.00	78.80	11.80
Crude Oil	5.800	20.33	1.00	74.54	10.29
Naphtha (<401°F)	5.248	18.14	1.00	66.51	8.31
Natural Gasoline	4.620	18.24	1.00	66.88	7.36
Other Oil (>401°F)	5.825	19.95	1.00	73.15	10.15
Pentanes Plus	4.620	18.24	1.00	66.88	7.36
Petrochemical Feedstocks	5.428	19.37	1.00	71.02	9.18
Petroleum Coke	6.024	27.85	1.00	102.12	14.65
Still Gas	6.000	17.51	1.00	64.20	9.17
Special Naphtha	5.248	19.86	1.00	72.82	9.10
Unfinished Oils	5.825	20.33	1.00	74.54	10.34
Waxes	5.537	19.81	1.00	72.64	9.58

Source: EPA Climate Leaders, Stationary Combustion Guidance (2007), Table B-2 except:
Default CO_2 emission factors (per unit energy) are calculated as: Carbon Content × Fraction Oxidized × 44/12.
Default CO_2 emission factors (per unit mass or volume) are calculated as: Heat Content x Carbon Content × Fraction Oxidized × 44/12× Conversion Factor (if applicable). Heat content factors are based on higher heating values (HHV).

Table B.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

U.S.EPA National Pollutant Discharge Elimination System (NPDES) Development Document, Chapter 5, "Industry Subcategorization for Effluent Limitations Guidelines and Standards". Adapted from Moser et al. (1999).

Table B.10. Baseline Assumptions for Greenfield Projects

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

The simplified assumptions contained within this table are based on the waste management system data compiled by the U.S. Environmental Protection Agency for the development of Table A-194 in Annex 3 of the U.S. Inventory of GHG Sources and Sinks 1990-2010 (2012).

Appendix C Summary of Performance Standard Development

The analysis to establish a performance standard for the U.S. Livestock Project Protocol (LSPP) was undertaken by Science Applications International Corporation (SAIC) and independent consultant Kathryn Bickel Goldman. It took place at the end of 2006. The analysis culminated in a paper that provided a performance standard recommendation to support the Reserve's protocol development process, which the Reserve incorporated into the protocol's eligibility rules (see LSPP Section 3). This analysis was re-visited during the development of Version 4.0 of the protocol and, although there was no recommended change to the performance standard, this appendix has been updated to reflect more recent data and analysis.

The purpose of a performance standard is to establish a threshold that is significantly better than average GHG production for a specified service, which, if met or exceeded by a project developer, satisfies the criterion of "additionality." The LSPP focuses on the following direct emission reduction activity: avoiding methane emissions from the anaerobic storage and treatment of livestock manure. Therefore, in this case the methane emissions correspond to GHG production, and manure treatment/storage correspond to the specified service.

The analysis to establish the performance standard evaluated U.S.- and California-specific data on dairy and swine manure management systems. Ultimately, it recommended a practice-based/technology-specific GHG emissions performance standard – i.e., the installation of a manure digester (or Biogas Control System (BCS), more generally). The paper was composed of the following sections:

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

The initial analysis from that paper can be found in earlier versions of the U.S. Livestock Project Protocol Performance Standard, Appendix C. In this updated performance standard appendix, the additional and California-specific analysis showed adoption rates similar to the rest of the country, and thus has been removed from this document to reflect the Reserve's decision to apply the same performance standard to all operations across the United States. Beef facility and animal information has also been removed as beef operations are not currently eligible under the methodology.

C.1 Analysis of Common Practice

C.1.1 U.S. Data on Manure Management Practices

For the initial performance standard analysis, data from the Draft EPA Climate Leaders Offset Protocol for Managing Manure with Biogas Recovery Systems (2006) were used to assess national-level manure management practices. That protocol relied on data describing farm distribution and manure management systems from the Manure Management portion of the

Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2004 and used data on the number of farms by farm size and geographic location from the 2002 Census of Agriculture.[28]

Information compiled for the EPA's U.S. GHG Inventory also provided a breakdown of the assumed predominant manure management systems in use for dairy and swine operations. Table C.1 and Table C.3 show data compiled for the systems in place in 2006. Table C.2 and Table C.4 show the Reserve's approximate recreation of the same analysis using the recently published numbers.[29]

Table C.1. Dairy and Swine Operations in the U.S. by Manure Management System (2006)

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

Source: U.S. EPA Climate Leaders Offset Protocol for Managing Manure with Biogas Recovery Systems (2008), Table I.A.

Table C.2. Dairy and Swine Operations in the U.S. by Manure Management System (2012)

Animal	Number of Operations by Manure Management System						
	P/R/P	Anaerobic Digester	Lagoon	Liquid/ Slurry	Solid Storage	Deep Pit	Total
Dairy	56,075	185*	3,332	3,261	6,263	775	69,890
Swine	55,110	30	5,740	4,641	892	9,029	75,442

Source: U.S. EPA GHG Inventory (2012), U.S. EPA AgSTAR Database (2012), U.S. Dept. of Agriculture, 2007 Census of Agriculture
* There are three systems in operation that digest both swine and dairy manure. For the purpose of this analysis they are considered as dairy.

The distribution of livestock across different sized operations can be an important criterion when developing a livestock manure management performance standard. There is a general relationship between manure management practices and operation size, where larger operations (in terms of livestock numbers) tend to use manure management systems that treat and store waste in liquid form (i.e., flush or scrape/slurry systems), particularly in dairy and swine operations.[30]

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[28] EPA GHG Inventory Reports in subsequent years (including 2010) still rely on the results of the 2002 Census for this data.
[29] The equivalent analysis based on the 2007 census is unavailable in the same format from the EPA Climate Leaders program. The Reserve performed a similar analysis using data for manure management from the Inventory of U.S. Greenhouse Gas Emissions and Sinks (2012), data on the prevalence of anaerobic digesters from the U.S. EPA's AgSTAR database (Sept. 2012), and data on the number of farms by farms size and geographic location from the 2007 Census of Agriculture, the results of which are Table C.2 and Table C.4. This analysis may not have been performed in precisely the same way as the EPA Climate Leaders Program analysis; however, it serves the purpose of evaluating the current state of the dairy and swine manure management practices. The following classification assumptions were made: 1. digester projects associated with farms of size are classified by based on other information in the AgSTAR database, if available, or assumed to be in the medium size class; 2. farms employing anaerobic digesters are subtracted from the USDA counts based on "Baseline System" or other information in the AgSTAR database, if available. Where the "Baseline System" is categorized as "Storage Tank or Pond or Pit," the farm is assumed to belong in the "Liquid/Slurry" category for Dairy and the "Deep Pit" category for Swine.
[30] U.S. Inventory of Greenhouse Gas Emissions and Sinks: 1990-2004 (and earlier editions), U.S. Environmental Protection Agency, Report # 430-R-06-002, April 2006.

Table C.3. Dairy and Swine Operations by Size and Manure Management System (2006)

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

Source: U.S. 2002 Census of Agriculture.

Table C.4. Dairy and Swine Operations by Size and Manure Management System (2012)

Animal	Number of Operations by Farm Size and Manure Management System							
	Farm Size	P/R/P	Anaerobic Digester	Lagoon	Liquid/ Slurry	Solid Storage	Deep Pit	Total
Dairy	≥500 head	312	154	1,824	710	284	-	3,284
	200-499	3205	25	502	531	44	-	4,307
	1-199	52559	6	1,006	2,020	5,934	775	62,299
Swine	≥2000 head	-	26	3,182	1,295	358	3,345	8,206
	200-2000	-	3	2,557	3,347	534	5,685	12,125
	1-199	55,110	1	-	-	-	-	55,111

Source: U.S. EPA GHG Inventory (2012), U.S. EPA AgSTAR Database (2012), U.S. Dept. of Agriculture, 2007 Census of Agriculture.

According to the Interim Draft Winter 2006 AgSTAR Digest used for the initial analysis, of 91,988 dairy and 78,894 swine farm operations in the United States, a total of 80 anaerobic digesters were in operation: 62 (0.07%) for dairy manure and 18 (0.02%) for swine manure.

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

The most current information from the AgSTAR database (September 2012) shows that the number of anaerobic digesters in operation or under construction has nearly tripled at dairy farms and increased by more than 50% at swine farms. In terms of prevalence as a manure management practice across farms however, the practice remains the exception, rather than the rule. Currently there are 185 digesters at dairy farms (0.14%), and 30 at swine farms (0.03%).

The number of digesters at the largest farms increased the most significantly, with 154 digesters at dairy farms with ≥500 head (4.69%), and 26 at swine operations with ≥2000 head (0.32%). Of the 185 dairy farms with anaerobic digesters in operation, 84 have participated in GHG offset programs; eight of the 30 swine farms with anaerobic digester have participated in GHG offset programs. Table C.5 shows the distribution and percentages of digesters in operation or under construction by size farm, compared to farms with other manure management practices; Table

C.6 shows the same distribution, but does not include the digesters at farms participating in GHG offset programs.

The “natural” market penetration of anaerobic digesters on livestock facilities can be considered as the percentage of farms that choose this management option without the incentive provided by GHG offset programs. Table C.6 shows that the natural market penetration of anaerobic digesters on dairy and swine facilities in the U.S. remains very low. The highest rate of adoption is among dairy farms with ≥500 head, at 2.31%. However, this number conservatively includes anaerobic digestion facilities that are currently under construction. As many if not all of these facilities may actually be installed in response to GHG offset programs (which is often not known until they are operational and become publicly listed in one of these programs), even this small rate of adoption is likely to be overestimated by this analysis. If the anaerobic digesters that are under construction are all assumed to be GHG offset projects, then the natural market penetration of anaerobic digesters on dairy facilities of ≥ 500 head drops to 1.71%.

Table C.5. Dairy and Swine Operations by Size and Manure Management System (2012)

Animal	Number of Operations by Farm Size and Manure Management System							
	Farm Size	P/R/P	Anaerobic Digester	Lagoon	Liquid/ Slurry	Solid Storage	Deep Pit	Total
Dairy	≥500 head	312 9.49%	154 4.69%	1,824 55.53%	710 21.63%	284 8.66%	- -	3,284
	200-499	3,205 74.41%	25 0.58%	502 11.66%	531 12.32%	44 1.03%	- -	4,307
	1-199	52,559 84.37%	6 0.01%	1,006 1.61%	2,020 3.24%	5,934 9.52%	775 1.24%	62,299
	Total	56,075 80.23%	185 0.26%	3,332 4.77%	3,261 4.67%	6,263 8.96%	775 1.11%	69,890
Swine	≥2000 head	- -	26 0.32%	3,182 38.78%	1,295 15.78%	358 4.37%	3,345 40.76%	8,206
	200-1999	- -	3 0.02%	2,557 21.09%	3,347 27.60%	534 4.40%	5,685 46.88%	12,125
	1-199	55,110 99.998%	1 0.002%	- -	- -	- -	- -	55,111
	Total	55,110 73.05%	30 0.04%	5,740 7.61%	4,641 6.15%	892 1.18%	9,029 11.97%	75,442

Source: U.S. EPA GHG Inventory (2012), U.S. EPA AgSTAR Database (2012), U.S. Dept. of Agriculture, 2007 Census of Agriculture.

Table C.6. Dairy and Swine Operations by Size and Manure Management System (2012) – Not Including Participants in a GHG Offset Program

Animal	Number of Operations by Farm Size and Manure Management System							
	Farm Size	P/R/P	Anaerobic Digester	Lagoon	Liquid/ Slurry	Solid Storage	Deep Pit	Total
Dairy	≥500 head	312 *9.73%*	74 *2.31%*	1,824 *56.91%*	710 *22.17%*	284 *8.88%*	- -	3,204
	200-499	3,205 *74.47%*	21 *0.49%*	502 *11.67%*	531 *12.33%*	44 *1.03%*	- -	4,303
	1-199	52,559 *84.37%*	6 *0.01%*	1,006 *1.61%*	2,020 *3.24%*	5,934 *9.52%*	775 *1.24%*	62,299
	Total	56,075 *80.33%*	101 *0.14%*	3,332 *4.77%*	3,261 *4.67%*	6,263 *8.97%*	775 *1.11%*	69,806
Swine	≥2000 head	- -	19 *0.23%*	3,182 *38.81%*	1,295 *15.79%*	358 *4.37%*	3,345 *40.80%*	8,199
	200-1999	- -	2 *0.02%*	2,557 *21.09%*	3,347 *27.60%*	534 *4.40%*	5,685 *46.89%*	12,124
	1-199	55,110 *99.998%*	1 *0.002%*	- -	- -	- -	- -	55,111
	Total	55,110 *73.06%*	22 *0.03%*	5,740 *7.61%*	4,641 *6.15%*	892 *1.18%*	9,029 *11.97%*	75,434

Source: U.S. EPA GHG Inventory (2012), U.S. EPA AgSTAR Database (2012), U.S. Dept. of Agriculture, 2007 Census of Agriculture, open GHG offset program registries.

Finally, as anaerobic digesters are most likely to be installed on livestock facilities that already utilize liquid-based manure management systems, it is useful to examine the market penetration among only these facilities. Table C.7 shows that, among the total facilities utilizing liquid manure management systems, the natural market penetration of anaerobic digesters is 1.35% for dairy farms and 0.11% for swine farms.[31] The highest rate, seen among dairy farms of ≥500 head, is 2.84%. This continues to be an extremely low rate of adoption for anaerobic digestion technology.

[31] There is seemingly 100% market penetration on swine farms with <200 animals, due to the fact that there was only one farm in the dataset utilizing liquid manure management, and it also had an anaerobic digester. A greater trend of adoption of anaerobic digestion cannot be drawn from this single farm.

Table C.7. Dairy and Swine Operations Utilizing Liquid Manure Management System, by Size and Manure Management System (2012) – Not Including Participants in a GHG Offset Program

Animal	Number of Operations by Farm Size Using Anaerobic Manure Management (Excluding GHG Offsets)			
	Farm Size	Anaerobic Digester	Liquid Manure Management	Total
Dairy	≥500 head	74 *2.84%*	2,534 *97.16%*	2,608
	200-499	21 *1.99%*	1,033 *98.01%*	1,054
	1-199	6 *0.16%*	3,800 *99.84%*	3,806
	Total	101 *1.35%*	7,367 *98.65%*	7,468
Swine	≥2000 head	19 *0.24%*	7,822 *99.76%*	7,841
	200-1999	2 *0.02%*	11,589 *99.98%*	11,591
	1-199	1 *100.00%*	- -	1
	Total	22 *0.11%*	19,410 *99.89%*	19,432

C.1.2 U.S. and State Manure Management Regulations

As a part of the Reserve's protocol management, regulatory developments are tracked through, among other outreach and research activities, reporting on regulatory requirements by project developers and verification bodies in the verification process. Of the farms with an anaerobic digester that have participated in GHG offset projects documented in EPA's AgSTAR program, 65 have listed their projects under the Reserve's U.S. Livestock Project Protocol. Twenty-seven projects have been registered with the Reserve, i.e., successfully undergone the verification process. This includes projects in four of the five top dairy producing states, namely, California, Wisconsin, Texas and Idaho. In states where registered Reserve projects are located, no state or federal regulations have been found that would require the use of a BCS.

C.2 Performance Standard Recommendation

The original SAIC report recommended that a performance standard apply to the control of methane emissions from dairy and swine livestock operations in the U.S. and California. In particular, the performance standard should be a technology-specific threshold that dairy or swine operators would meet. The recommended threshold would be the installation of a BCS (e.g., an anaerobic digester).

The report found that even under favorable conditions digesters were found on less than 1% of the dairies in California, which was found to be representative of the U.S. market; and that if a dairy operator chose to install a digester then the farmer would be managing waste in the 99th percentile. This constitutes above and beyond common practice. The report also found that the main barrier inhibiting the installation and use of digesters was cost. Cost studies performed by EPA's AgSTAR program and the California Electricity Commission indicated that significant subsidies and/or incentives were needed to encourage additional digester installations.

The Reserve adopted this performance standard recommendation based on the data available at the time of the SAIC report. While the number of anaerobic digesters has increased significantly, the market penetration of BCS technology remains quite low, especially among those farms which are not receiving revenues from GHG offset markets. Today a dairy operator who chooses to install a digester would be managing waste in the 98th percentile—a modest increase since the original analysis, but hardly a significant shift in common practice. Furthermore, cost continues to inhibit wider adoption of BCS technologies according to a recent EPA report on the status of anaerobic digester adoption.[32] In light of these facts, the Reserve will not alter the current performance standard, but will continue to monitor market developments in the future.

C.3 Renewable Energy Certificates and Other Revenue Opportunities for Biogas-to-Energy Projects

Along with carbon credits, there are opportunities for farms installing digesters to earn additional revenues from a variety of sources that support renewable energy generation. These include loans and grants for developing biogas-to-energy projects and the sale of Renewable Energy Certificates (RECs) for use in a renewable portfolio standard (RPS) or a renewable portfolio goal (RPG).[33]

When considering additionality and the ability to generate RECs and CRTs from a livestock project, it is important to remember that the REC and CRT are created by two different but related activities. The REC is awarded for generating renewable electricity from the biogas collected by the BCS, whereas the CRT is awarded for the climate benefit created by the conversion of CH_4 in the biogas into CO_2 through combustion of the biogas. Under the LSPP, projects are not required to generate electricity with collected biogas or send it to a natural gas pipeline. Rather, they are only required to destroy the biogas. While a project may generate renewable electricity with its biogas, renewable energy generation is not an activity required or credited under the LSPP.

As there are a number of active RPS, RPG and voluntary REC programs nationwide, the availability of revenue from the sales of RECs is inherently represented in the data analyzed to set the performance standard. Since this analysis shows that the installation of a digester is not common practice at dairy and swine farms, the Reserve does not limit a project's ability to generate or sell RECs. Due to the numerous barriers to implementation of an anaerobic digester project, their success typically relies on a complex array of factors, including multiple incentive program. Renewable energy incentives alone have not significantly increased the natural market penetration of these projects.

When considering additionality and the availability of public dollars to support the development of biogas-to-energy projects, the Reserve has identified numerous state and local programs to support such projects through grants, loans and payments. Although the Reserve's performance standard tests do not require individual project assessments of financial viability or returns, they are designed to reflect these factors in determining which projects are additional. Even with the funds available, the installation of anaerobic digesters according to the LSPP is still very rare. Thus, even if a project does receive a grant or loan to support the generation of renewable

[32] U.S. Anaerobic Digester Status Report, October 2010, http://www.epa.gov/agstar/documents/digester_status_report2010.pdf
[33] Whereas compliance with an RPS is mandatory, RPGs set voluntary compliance targets.

energy from a biogas project, the performance standard and rules set forth in the LSPP should ensure the additionality of the CRTs generated.

Beyond grants and loans for biogas-to-energy projects, there are two nationwide payment programs administered by USDA Natural Resource Conservation Service (NRCS) that support the installation of anaerobic digesters. Authorized by the 2008 Farm Bill, the Environmental Quality Incentives Program (EQIP), and the Chesapeake Bay Watershed Initiative (CBWI) are programs that provide payments to support the installation of a BCS and are implemented at the state- and county-level. NRCS expressly allows the sale of environmental credits from enrolled lands, but does not provide additional guidance on ensuring the environmental benefit of any mitigation payment stacked with an NRCS payment.[34]

All NRCS programs share a common set of conservation practice standards that contain information on why and where the practice is to be applied, and set forth the minimum quality criteria that must be met during the application of that practice in order for it to achieve its intended purpose(s).

NRCS Conservation Practice Standard 366 – Anaerobic Digester (CPS 366) provides assistance to farmers for the treatment of manure and other byproducts of animal agricultural operations for one or more of the following reasons: to capture biogas for energy production, to manage odors, to reduce the net effect of greenhouse gas emissions, or to reduce pathogens.[35]

Data obtained from NRCS show that less than 0.3% of farms eligible for funding under CPS 366 (i.e., farms with anaerobic operations) have received NRCS funds to install a BCS.[36] In practice, only 9% of the farms that installed BCS since 2004 have received NRCS funds. Because the installation of anaerobic digesters is expensive, uncommon and generally not already funded by NRCS programs, the use of NRCS payments to help finance project activity is allowed under the LSPP.

[34] EQIP, 7 CFR §1466.36; CSP, 7 CFR §1470.37.
[35] Natural Resources Conservation Service. (September 2009). Conservation Practice Standard, Anaerobic Digester, Code 366. State-specific conservation practice standards can be downloaded from http://efotg.sc.egov.usda.gov//efotg_locator.aspx.
[36] Based on 2004-2011 data obtained from NRCS Resource Economics, Analysis and Policy Division through personal communication.

Appendix D Risk Assessment[37]

This risk assessment presents a methodology for projecting project performance and project longevity on the basis of existing, publicly available data on existing dairy methane capture and destruction projects.

This risk assessment utilizes quantitative uncertainty analysis. Quantitative uncertainty analysis of emissions estimates is typically performed by estimating the 95 percent confidence interval of known emissions or removals for particular categories.[38] Details related to the quantification of specific project parameters for livestock offset projects, contained within monitoring and verification reports submitted to offset registries, are typically confidential and therefore not publicly available. However, aggregate estimates of baseline emissions, project emissions, and emission reductions are routinely included in public registry reports. Aggregate emissions scores incorporate the variability associated with individual monitored parameters in quantification models, and their use in uncertainty analysis and estimation may also avoid the potential for compounded error associated with the combined use of multiple specific parameters that may be correlated, leading to overestimation of the variability of the emissions score of primary interest—in this case, emission reductions over time for dairy manure anaerobic digestion projects in the U.S.

D.1 Variability in emission reductions from dairy digester projects

D.1.1 Offset Registry Data

Emissions data from U.S. dairy digester GHG offset projects were obtained from publicly-available online reports provided by two active GHG offset registries: The Climate Action Reserve[39] and American Carbon Registry[40] (ACR). Registry data for the livestock methane capture project type were presented by reporting period for each project, and included project name and registry ID, period start and end dates, quantification methodology (protocol and version) employed, baseline emissions, project emissions, metered emission reductions, modeled emission reductions, and total emission reductions issued as offset credits. Emissions data were presented as metric tons (Mg) CO_2e per reporting period.

D.1.2 Data Management

For the purposes of this analysis, the project start date was defined as the start date of the first reporting period for each project. For most projects, this represented the start of the initial offset program crediting period, rather than the actual commencement of project operations. The timing of emissions data for each project reporting period was expressed as the number of years from the project start date to the end of the reporting period (Project Years).

Project reporting periods varied in duration. Some offset program protocols required discrete reporting periods within a calendar year; others allowed reporting periods to extend across calendar years. The minimum reporting period duration in the collected registry data was nine days, and the maximum was two years. To reduce seasonal variability, emissions data from reporting periods using the same protocol version, and ending in the same calendar year, were combined (summed) for each project. After this adjustment, any reporting periods with a

[37] Appendix D is a modified version of a white paper prepared by ClimeCo Corporation.
[38] For example, see 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Chapter 3, Uncertainties.
[39] https://www.climateactionreserve.org/
[40] https://americancarbonregistry.org/

duration of less than 180 days were excluded from statistical analyses. To adjust for the differences in reporting period duration, emissions data were converted to Mg CO_2e per day.

For individual analyses of specific emissions scores (e.g., baseline emissions, project emissions, and emission reductions), records with missing or zero-values were also excluded (the latter since zero-credit reporting periods, in most cases, likely resulted from programmatic issues such as insufficient data or regulatory non-compliance, and therefore did not represent actual emissions). The first reporting period for each project was often of short duration, and for many projects, emissions scores for the first reporting period were considerably lower than for other reporting periods. This is likely a result of offset program-related start-up issues related to implementation of monitoring and documentation requirements. Therefore, the first reporting period for all projects was excluded from analyses. Finally, projects for which there were less than three reporting periods (in the combined and filtered data set, after excluding the first reporting period) were excluded from analyses, since data from at least three reporting periods were required to adequately assess within-project variability.

The resulting data set included 56 projects, representing 271 adjusted reporting periods. The number of reporting periods per project ranged from three to eight, with a median of five. The duration of each project ranged from 2.9 – 9.0 project years, with an average of 5.8 project years.

D.1.2 Emission Reductions

To evaluate the variability of emission reductions for dairy digester projects we used the statistical program R and the *lme4* and *nlme* packages to perform a linear mixed effects analysis of the relationship between emissions score and time, while accounting for repeated measurements within projects. Time (in project years) was the sole fixed effect in the model. As random effects, we included intercepts for projects, as well as by-project random slopes for the effect of time. Visual inspection of residual plots showed no obvious deviations from the standard assumptions of normality and homoscedasticity. P-values were obtained by a likelihood ratio test of the full model containing the time effect against the model without the time effect. For each project, emission reductions for each reporting period were plotted as a function of time (Figure D.1).

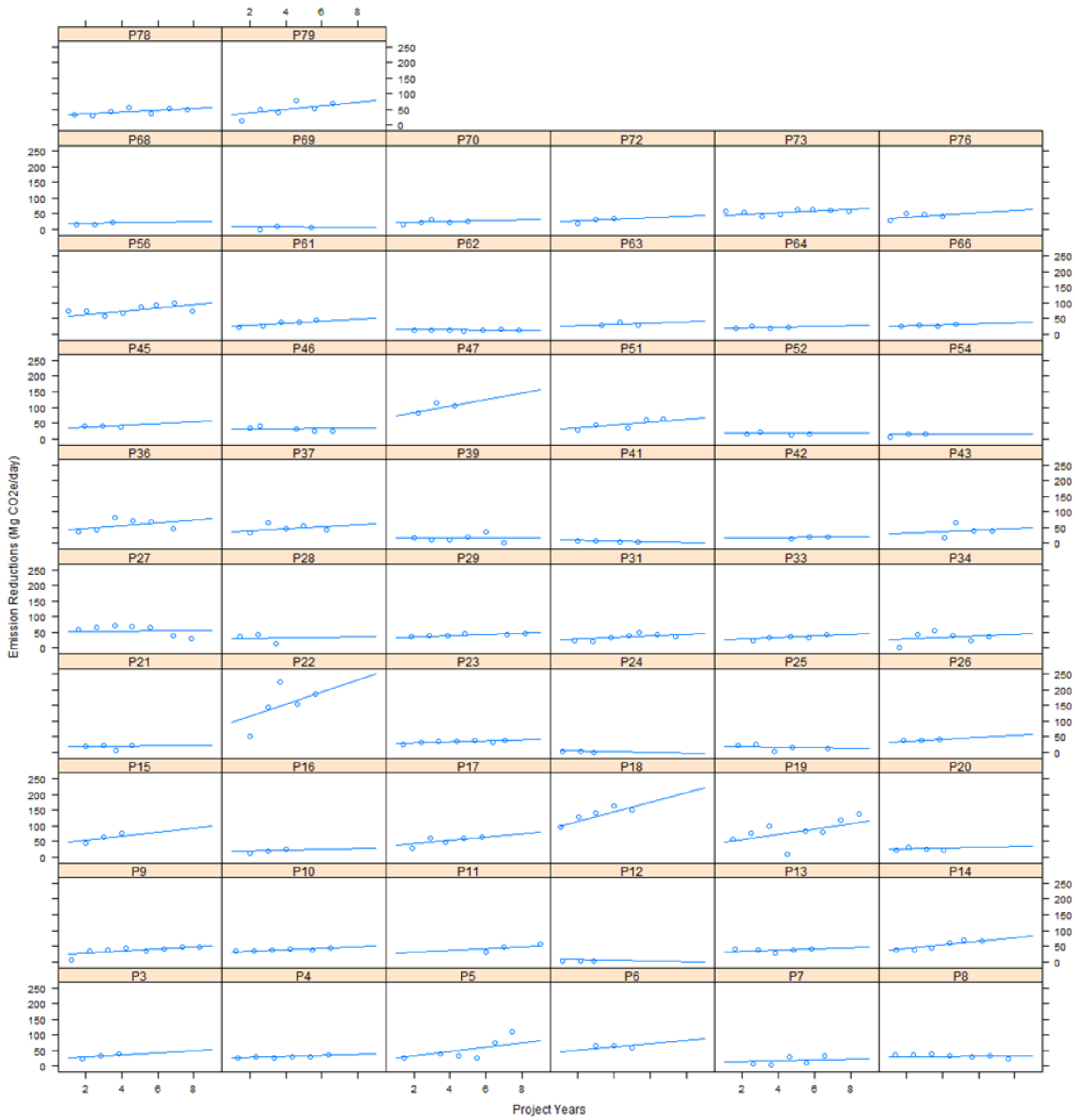

Figure D.1. Emission Reductions as a Function of Time (Project Years) for 56 Individual Projects (P3 – P79)

Independent intercepts and slopes (indicated by the solid lines) were modeled with linear mixed effects analysis with Project Years as the fixed effect and by-project intercepts and slopes as random effects.

Mean project emission reductions ranged from 0.9 – 226.0 Mg CO_2e/day. Linear mixed effects analysis indicated a significant overall increase in emission reductions with time ($p < 0.001$). The solid lines in Figure D.1 indicate the slopes modeled for each project. The effect of time varied among projects; however, positive slopes were observed for 49 of the 56 projects. Figure D.2 shows a plot of emission reductions as a function of time for all of the project reporting periods evaluated, including the modeled overall regression line and its 95% confidence bands. On average, emission reductions increased annually by about 2.86 Mg CO_2e/day (1,044 Mg CO_2e/year).

Similar analyses were conducted for baseline and project emissions for each project reporting period. As with emission reductions, baseline emissions showed a significant overall increase with time (4.3 Mg CO_2e/day each year; $p < 0.001$). Project emissions showed no significant effect with time.

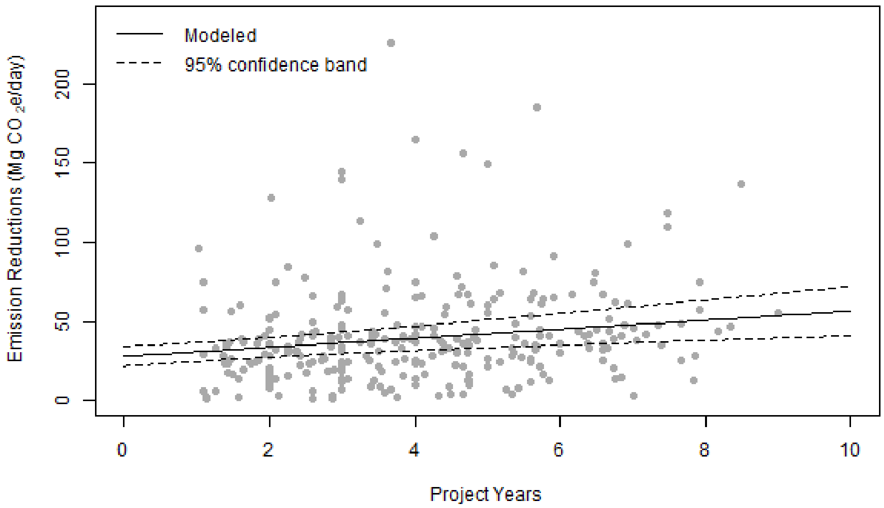

Figure D.2. Emission Reductions as a Function of Time (Project Years) for 56 Dairy Digester Projects
The regression line (solid line) and 95% confidence bands (dashed lines) were modeled with linear mixed effects analysis with time as the fixed effect and by-project intercepts and slopes as random effects.

The maximum potential emission reductions for an offset project is dependent on, and constrained by, the quantity of baseline emissions. For the sampled projects, baseline emissions and emission reductions are highly correlated ($p < 0.001$, $r^2 = 0.75$). Therefore, the observed increase in emission reductions with time appear to be related to corresponding increases in baseline emissions. Conventional offset methodologies for livestock projects employ a dynamic baseline, under the assumption that operational changes at dairy projects that impact baseline emissions would have happened with or without the project activity. The significant increase with time, observed for both baseline emissions and emission reductions, most likely results from increases in animal numbers and/or improvements in manure management at many of the project dairies.

To further evaluate the effect of time on project emission reductions, the data used in the previous analysis were transformed, by project, to represent the percentage deviation of the emissions score for each reporting period from the initial reporting period for that project:

$$\boldsymbol{TE_{p,rp} = \left(E_{p,rp} - E_{p,rp_0}\right)/E_{p,rp_0}}$$

Where,

$TE_{p,rp}$	=	Transformed emissions score for each project *p* and reporting period *rp*
$E_{p,rp}$	=	Emissions score for each project *p* and reporting period *rp*
$E_{p,rp0}$	=	Emissions score for the initial reporting period rp_0 within each project *p*

Observations for the initial reporting periods rp_0 were then dropped to avoid biasing the results (since information from the initial reporting periods was incorporated in the transformed scores for the subsequent reporting periods for each project). Also dropped was data from a single project (P34) that, upon transformation, represented an extreme outlier due to the very small emissions score for the initial reporting period relative to subsequent reporting periods.

Linear mixed effects analysis of the relationship between transformed project emission reductions and time, accounting for repeated measurements within projects, was performed as above. Time (as project years from the initial reporting period, by project) was the sole fixed effect in the model. As random effects, intercepts for projects were included, as well as by-project random slopes for the effect of time. As before, visual inspection of residual plots showed no obvious deviations from the standard assumptions of normality and homoscedasticity, and P-values were obtained by a likelihood ratio test of the full model containing the time effect against the model without the time effect.

Results of the analysis of the transformed emission reduction data are presented in Figure D.3. Overall, the deviation of emission reductions from the associated project's initial value increased significantly with time ($p < 0.001$)—about 8% per year on average. Notably, the lower 95% confidence band around the modeled regression line also increased with time and was greater than zero throughout. This indicates that, for a typical project, emission reductions in the years following the first reporting period have a greater than 95% probability of being greater than the emission reductions observed for the first reporting period.

Therefore, within a GHG mitigation program for dairy digester projects that employs a quantification methodology fundamentally similar to conventional livestock offset project methodologies, multiplying the quantity of annual emission reductions estimated at the commencement of project operations by the number of years in the project's crediting period represents a conservative approach for forecasting the total emission reductions achieved by a project during its crediting period (assuming project activities continue without disruption during the crediting period).

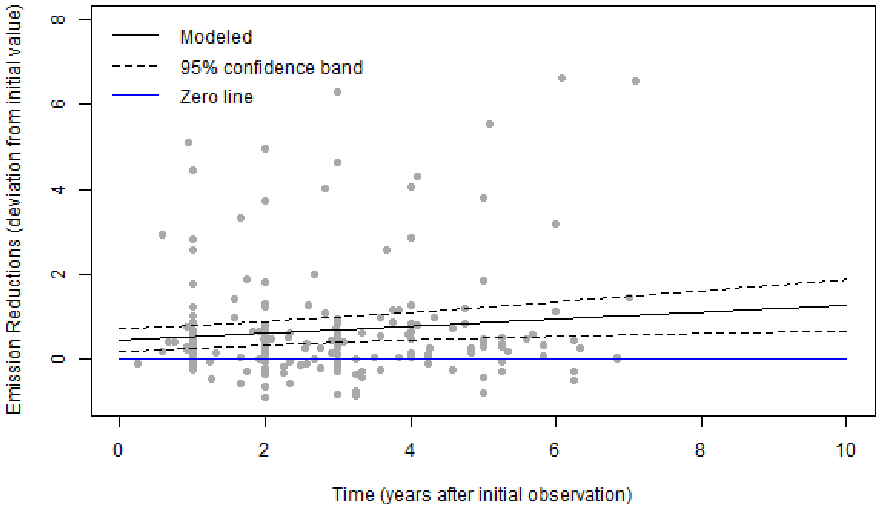

Figure D.3. Deviation of Project Emission Reductions from the Associated Project's Initial Value as a Function of Time (Years after the Initial Observation) for 55 Dairy Digester Projects

The regression line (solid line) and 95% confidence bands (dashed lines) were modeled with linear mixed effects analysis with time as the fixed effect and by-project intercepts and slopes as random effects.

D.2 Longevity of Dairy Digester Projects

The use of anaerobic digesters for manure treatment by U.S. dairies is a relatively recent development—the first dairy digester project in the U.S. began operations in 1979 (and is still operational 38 years later).[41] Significant changes in market penetration, technologies employed, business models, and financial and regulatory incentives for anaerobic digesters at dairy and other U.S. livestock operations have occurred in recent decades. Therefore, the relevance of historical data for developing meaningful probabilities for forecasting the longevity of future dairy digester projects is questionable. As technologies, operating experience, business models, and financial and regulatory incentives continue to evolve, information from historical data must be evaluated within the context of a rapidly changing, emerging industry.

D.2.1 AgStar Database

The U.S. Environmental Protection Agency (EPA), through its AgStar Program[42], tracks the historical development and status of anaerobic digesters on livestock farms in the U.S. The AgStar Livestock Anaerobic Digester Database[31] (AgStar database) is compiled from voluntary sources, so the completeness and accuracy of the information is not guaranteed; nevertheless, it represents the most complete publicly available history of U.S. dairy digester performance and longevity. The AgStar database also contains useful information regarding reasons for failure of individual projects that ceased operations. Information from the AgStar database pertaining to farm-scale dairy digester projects was analyzed to gain insight into the risk of failure for future dairy digester projects.

D.2.2 Data Management

The AgStar database was downloaded from the EPA website. The version used for analysis was last updated in November 2017. The database contained two tables: one listing projects

[41] U.S. EPA AgStar Livestock Anaerobic Digester Database (November 29, 2017)
[42] https://www.epa.gov/agstar/livestock-anaerobic-digester-database

that were under construction or operational, the other listing terminated ('shut down') projects. From both tables, we selected only those livestock operations that were classified (solely) as dairy and represented farm-scale projects (since community digester projects are much less common and have their own unique history of success or failure). Farm-scale projects that were not classified in the AgStar database by livestock operation type were reviewed and, based on professional experience and a web search, some of these projects were reclassified as dairies. Projects classified as 'in construction' were excluded, leaving only projects that were classified as either operational or shut down. The resulting dataset represented 210 farm-scale dairy digester projects; 171 were listed as operational, and 39 as shut down.

D.2.3 Results

Of the 210 farm-scale dairy digester projects selected from the AgStar database, about 80% operated for five or more years, 32% for ten or more years, and 10% for fifteen or more years. However, the inclusion of recently-started operational projects biases these results toward projects with shorter duration (e.g., for an operational project that started three years ago, it is not possible to know how long the project will continue until termination, but the project duration, to date, is only three years). If only operational projects that were started ten or more years ago (before the year of the database update: 2017) are included with all the terminated projects in the analysis, about 68% of the 99 projects operated for at least ten years, and about 18% operated for at least fifteen years; average project duration was 10.8 years. The frequency distribution and cumulative frequency distribution of project duration for these projects is plotted in Figure D.4. With time, the frequency distributions would be expected to shift to the right (increasing average project duration), unless many of the operational projects suddenly terminated.

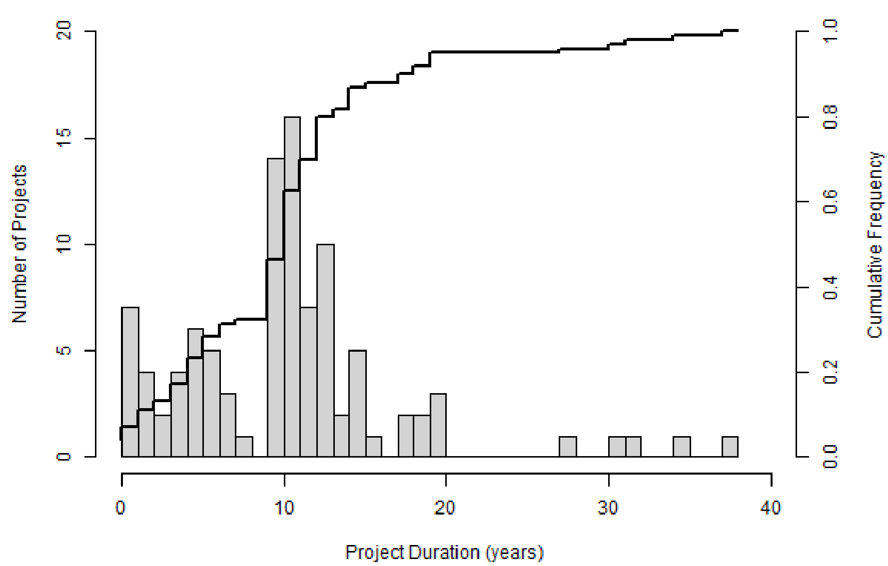

Figure D.4. Frequency Distribution and Cumulative Frequency Distribution for Dairy Digester Project Duration

Frequency distribution (bars) and cumulative frequency distribution (solid line). Data includes farm-scale dairy projects classified as 'shut down', and projects classified as 'operational' and started before 2008, in the AgStar database.

D.2.3 Causes of Project Termination

For the 39 farm-scale dairy digester projects classified as ‘shut down’, the average project duration was 7.0 years. About 44% of the projects operated less than five years before termination, 38% operated between five and nine years, and 18% operated for ten or more years (all of these had project durations of fifteen years or more). For 21 of these projects, brief explanations of the reasons for project termination were included in the AgStar database. The explanations largely fell within the general categories listed in Table D.1 (for some projects, more than one category).

Table D.1. Reasons for Termination of 21 Dairy Digester Projects Included in the AgStar Database (Some projects were scored in multiple categories)

Category	*Description*	*Projects*	*Percent of Total*	*Avg. Duration (yrs)*[1]
Financial	Lack of adequate finances or financial incentives, including developer bankruptcy	6	29%	2.3
Design	Inadequate digester system performance relative to initial design expectations	4	19%	5.5
Operating	Major or catastrophic equipment/system failures	8	38%	4.3
Regulatory	Changes in regulatory requirements requiring significant project modifications	1	5%	3.0
Dairy Closure	Cessation of dairy operations or change of control	5	24%	6.6
Other	Not specified, but described as unrelated to digester system performance	1	5%	1.0

[1] Differences in average project duration among categories were not significant, as determined by multi-factor ANOVA.

Although the AgStar database provides insight into historical performance of farm-scale dairy digester projects, regarding project longevity and reasons for termination, it does not provide sufficient information, by itself, to accurately forecast the longevity of future projects as the industry matures and technologies, performance, and financial incentives improve. Indeed, many recent dairy digester projects have been developed and financed with an expectation of project lifetimes exceeding fifteen to twenty years, and include design, operational, and financial features that mitigate the risk of failure.

Clearly, not all dairy digester projects are alike; each carries specific risks related to project longevity including local circumstances, dairy operation stability, and aspects of project finance, design, and operation. For a GHG mitigation project, individual projects can be assigned to risk levels (low, moderate, and high) based on the demonstration and confirmation of specific mitigation activities and measures undertaken by the project prior to commencement. Table D.2 lists mitigation requirements, corresponding to the general categories identified above as reasons for project termination[43], required for projects to demonstrate appropriate project longevity factors have been implemented. The implementation of all of these mitigation measures ensures projects will realize projected emission reductions without major disruption or termination during the project crediting period.

The mitigation requirements for a dairy digester project includes: i) adequate demonstration that the project’s primary digester and biogas utilization technologies are commercially available, proven, and appropriate for the specific project design (innovative or unproven technologies carry significant uncertainty and are not considered to be appropriate for use within a mitigation

[43] Excluding less frequent regulatory issues (discussed in Section 3 of the methodology).

program); ii) an Operations Plan that adequately addresses long-term maintenance and operation of related project equipment within stated performance standards; and iii) adequate demonstration of the long-term financial stability of the livestock operation. Additional mitigation measures increase the probability of successful project completion for the entire crediting period.

Table D.2. Project Longevity Adjustment Factor: Mitigation Measures that must be Implemented to Reduce the Risk of Project Underperformance

Category	***Mitigation Measure***
Financial	Commercial contracts for long-term supply of digester products (e.g., electricity, biogas), including delivery incentives/penalties, for the duration of the crediting period.
	Proforma demonstration of sufficient cash flows to sustain project viability during the crediting period.
	Demonstrated long-term financial stability of the project operator.
Design	Demonstration that the primary digester and biogas utilization technologies are commercially available, proven, and appropriate for the specific project design.
	Basis of Design documentation for the digester system including a manure volatile solids mass flow diagram and estimated annual biogas production.
Operating	Operations Plan that ensures long-term maintenance and operation of related project equipment within stated performance standards.
	Long-term service warranties or contracts that include guarantees of rapid response for related equipment repairs.
Dairy Closure	Demonstration that the project is not located within a probable range of accelerated commercial/residential development.
	Demonstrated long-term financial stability of the livestock operation.
	Long-term commercial milk or animal supply contracts with delivery penalties impacted by reduced herd size, OR, contractual penalties for reducing animal numbers during the project crediting period.

Appendix E Sample Dairy Project Diagram