Carbon Accounting Methodology for Biogas

DRAFT 1.0 — March 8, 2024

Developed by EcoEngineers for the American Biogas Council

This is a draft version of the Carbon Accounting Methodology for Biogas. This methodology aims to build on existing compliance and voluntary carbon market methodologies to properly account for all life-cycle carbon emissions related to biogas production of any kind. The goal is to provide this science-based methodology to any entity generating carbon-based policy or credits to ensure carbon accounting is consistent and accurate across many of the ways biogas can be produced and their associated carbon intensities. Comments will be accepted at carbon@americanbiogascouncil.org until [date of the next version is expected out]. If you are reviewing this document after this date, please contact us at the previous email for an updated version to review.

AMERICAN BIOGAS COUNCIL

Prepared by:

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Table of Contents

1.0 General Conditions

1.1 Methodology Intent

This methodology aims to build on existing regulatory programs and voluntary carbon market (VCM) methodologies to supplement the needs and interests of the biogas industry. Specifically, these needs include:

- Providing an opportunity to calculate carbon intensity (CI) for biogas projects on an emission per energy basis (g CO_2e/MJ) and based on the fate of the product where the destination of its product is unique.
- Providing an opportunity for biogas projects to convert their CI score calculated with this methodology to an equivalent greenhouse gas (GHG) reduction amount.
- Providing an opportunity for biogas projects to account for and capture more environmental monetary benefits around their digestate.
- Providing an opportunity for users of this methodology to open the door for future conversations around practical applications within the VCM industry.

It establishes a transparent and consistent carbon accounting framework and provides a fundamental measurement methodology for potential emission reduction claims from biogas systems.

This methodology offers policymakers a template to include biogas in their energy transition and climate plans, which utilize energy and non-energy purposes of biogas. Combustion is the most common practice as an end use for biogas and is the focus of this methodology; however, other emerging technologies can also fit under this document with additional considerations. It also allows users of the methodology using biogas for heat, transportation, or electricity to assess their emissions.

It is based on broadly accepted and industry-approved conservative carbon accounting principles and creates the foundation for a standard CI calculation for biogas projects. As a result, it is hoped that this methodology's approach will allow for more biogas projects to be built by creating a pathway to account for and monetize the benefits they create.

Finally, this methodology was prepared by EcoEngineers for the American Biogas Council (ABC) and the biogas industry. Together, both organizations sought industry-wide feedback and input through a variety of channels during its creation.

1.2 User Guidelines

The current version of this biogas methodology comprises two pathways:

1) Framework for assessment of CI.
2) Framework for assessment of entrance into the VCM.

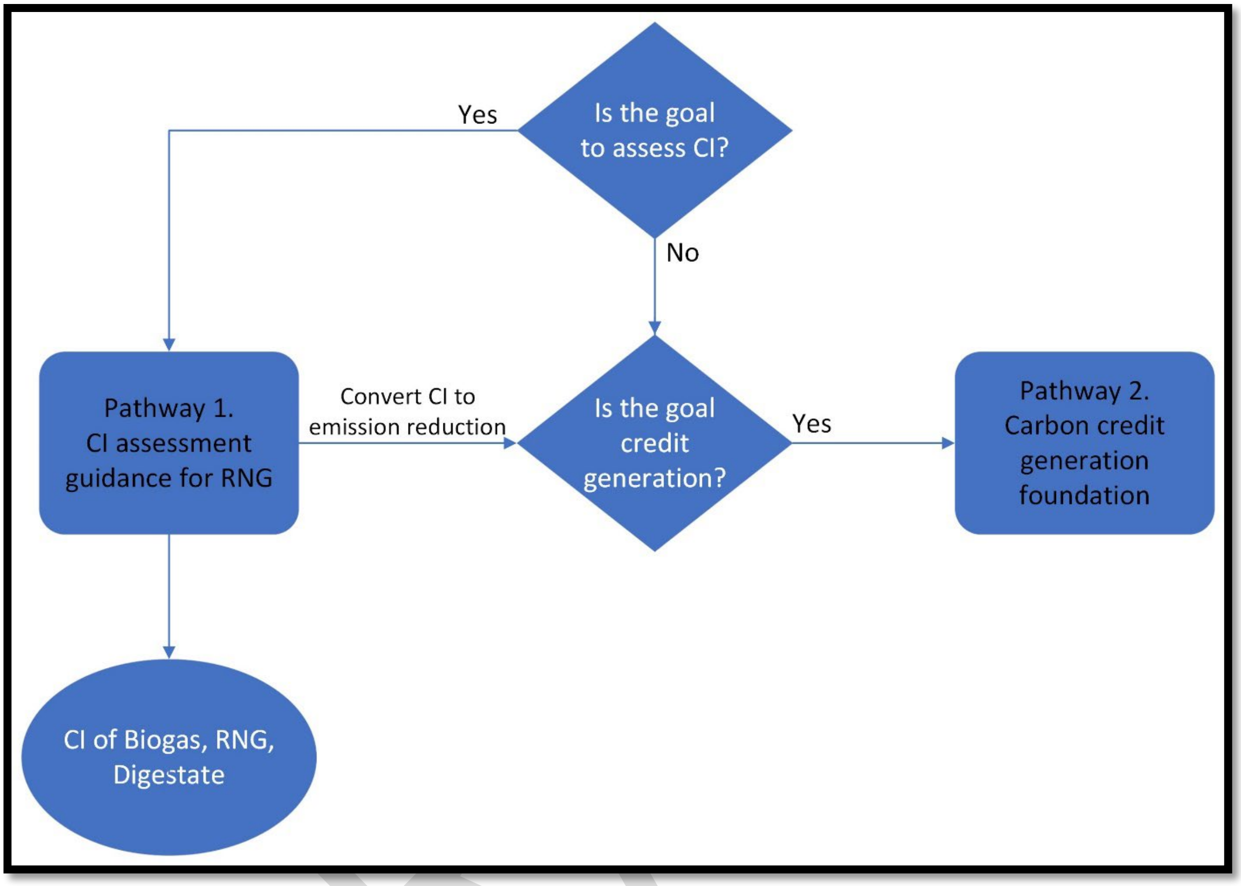
Users of this document are welcome to use either pathway or both, depending on their specific needs. In addition, the principles described hereafter can be used in compliance and voluntary markets.

The first pathway can be used for quantification purposes to justify assessments of GHG emissions. This is the focus of the current version of this document and detailed guidance is provided in the subsequent sections regarding each project type. In addition, at the end of each project-specific section, a summary is provided distinguishing differences between this quantification guidance and existing California Greenhouse Gases, Regulated Emissions, and Energy Use in Technologies (CA-GREET) methodology.

The second pathway may bring more benefits if the project aims to register its project in a VCM standard or registry. In this case, project developers can use the methodology as a base to add to existing registries as it provides a solid foundation for a credit issuer to estimate, verify, and credit environmental attributes of the project. The current version of this document does not provide a full methodology for carbon crediting, and it is up to project developers to consult and cooperate with certain registries to generate credits based on this framework. If this foundation is used for generating credits, project developers should consider minimizing risks including but not limited to regulatory changes that may impact the additionality of activities and/or changes in market practices that may shift the threshold for best performance.

Once the first pathway is used and CI assessment is done, users may decide to pursue crediting pathways. Third-party sources will be responsible for performing the auditing and crediting of pathways. For this purpose, emissions reduction should be assessed based on the conversion of CI (see Section 1.7 – Quantifying GHG Reductions) and the number of credible reductions should be estimated. Figure 1.2.1 below gives guidance on decision-making regarding this methodology's application.

Figure 1.2.1: User Guideline Decision-Making Chart



1.3 Methodology Background

Biogas, which is 30% to 90% methane, is produced by microbial metabolic activity. Microscopic bacteria and archaea consume organic matter in the absence of oxygen (i.e., anaerobic digestion) and generate methane gas, a fuel that can be used to produce energy (heat and electricity), or further refined and compressed, to produce advanced fuels. Microbial decomposition of organic waste, along with composting and other similar practices, is a very efficient waste management strategy.

Human society produces vast amounts of organic waste such as agricultural residues, food waste, sewage, and animal manure. Globally, organic waste generation is reaching critical thresholds. Anaerobic digestion and biogas production have proven to be effective ways to recycle this waste and extract energy from the biogenic carbon contained in it.

Biogas systems deliver multiple benefits: they provide basic waste management solutions, improve animal and human health and hygiene; generate renewable, clean energy; and they produce renewable fertilizer when the residue is digestate. They are a true representation of a circular system where the organic residue of a process is upcycled to create greater value. In addition to the core energy or nutrient value, the total environmental benefit of a biogas system includes the avoided use of fossil fuels or synthetic fertilizer. In regions where accumulated organic waste is a public nuisance or a health hazard, biogas treatment systems also provide an added advantage to modern, efficient sanitation infrastructure, advancing economic development, and improving quality of life.

Upgraded biogas (renewable natural gas or RNG), electricity from biogas, and digestate are low-carbon alternatives to the status quo, conventional, geologic natural gas, fossil-fuel dominated electric grid, and synthetic, chemical fertilizers that are derived from fossil fuels and carry a large carbon footprint. By substituting fossil sources of energy, power, and nutrients with comparable products sourced from biogenic feedstock (organic waste), there can be a claim of carbon reduction. The exact quantification of such a claim is embodied in a CI score. The CI score of a fuel or product represents the number of emissions (carbon dioxide equivalent, CO_2e) emitted to the atmosphere across the supply chain from production to its ultimate end use. The CI is expressed on an emissions per energy basis. The CI score of a more sustainable fuel or product when compared to a baseline or benchmark allows for quantifying the potential GHG emission reduction achieved in metric tonnes (MT) of CO_2e. This reduction in CO_2e can be sold on various carbon trading platforms and markets or can be used for internal carbon reduction goals by a corporation or public entity.

The ability to embody the carbon reduction in a product and state the reduction on a product label is available in several policies that try to reduce emissions. California, Oregon, Washington, Canada, and the European Union (EU) have enacted low-carbon fuel standard (LCFS) programs for the transportation sector where specific pathways for RNG or biogas electricity are eligible to generate credits. Similarly, non-governmental organizations and voluntary registries such as the Climate Action Reserve, American Carbon Registry, and M-RETS have also established methodologies and tracking systems recognizing carbon capture or destruction to generate credits for the avoided methane emissions that can occur at landfills, wastewater treatment plants, organic waste digesters, and livestock operations.

However, the rules governing the creation of these credits and their subsequent transactions can differ from program to program (e.g., the California Low Carbon Fuel Standard, or CA-LCFS, currently recognizes avoided methane emissions from anaerobic digestion of dairy manure but not from beef cattle manure, poultry litter, rice straws, etc.). Similarly, some voluntary registries do not accept any project associated with animal manure even if other voluntary or compliance certificate registries will accept those feedstocks. Rules of additionality, acceptable baselines, and approaches to book-and-claim for biogas delivery also vary from policy to policy. This methodology complies with industry-wide accepted emissions accounting principles, such as the World Resources Institute (WRI) or International Organization for Standardization (ISO), Various project types may have different coverage, boundaries, etc. compared to different GHG programs, as described further below, but the main principles are consistent throughout this and other methodologies.

The demand for carbon reduction products and circular economic models has never been stronger. Carbon accounting, carbon reporting, and product carbon labeling are emerging as some of the biggest business disruptors of the 21st century. Corporate business entities across the spectrum are seeking to incorporate circularity and carbon reduction/removal into product strategies, supply chains, and operations throughout their value chains. Consistent, scientifically justified messaging surrounding such efforts, using the framework of this methodology, will foster competitive differentiation, growth, and value creation.

1.4 Methodology Boundaries

This methodology attempts to capture the most common biogas facilities currently operational or in development in North America. Specifically, these include:

1. Animal manure management systems
2. Landfills
3. Wastewater treatment plants (WWTPs)
4. Food waste digesters
5. Other waste digesters

In addition, digestate will be addressed as a co-product of each of the applicable project types.

The above categories capture most project types, reaffirming the critical role of biogas systems. Business-as-usual practices represent the absence of controlled anaerobic digestion activities and, therefore, the absence of biogas recovery.

Another growing category of biogas system feedstock is herbaceous plant material, often from temporary crops. These crops are typically grown, not as a saleable commodity, but to provide specific, environmental goals. For example, winter rye is planted in the U.S. Midwest to prevent soil erosion and nutrient loss. Similarly, edge-of-field buffer zone crops prevent soil and nutrient loss, create wildlife habitats, and reduce flood impacts. If these crops are harvested, they can be used in biogas systems as additional feedstock. However, the lack of data from existing projects makes it difficult to set baselines and quantify the diverse, environmental benefits.

This methodology does not address biogas production from dedicated crops that are grown for energy harvest purposes; however, the waste from those cultivations can be considered for biogas projects. A direct land-use impact assessment should be the basis of a CI calculation for these types of projects.

It is the objective of this methodology to encourage innovation and new project development. The methodology as written here focuses on project types that are already in place and produce most of the biogas available as of this methodology's release date. As new project types are introduced, the methodology will be periodically updated to capture those innovations.

1.5 GHG Accounting Principles

The World Resources Institute/World Business Council for Sustainable Development (WRI/WBCSD) Greenhouse Gas Protocol for Project Accounting has developed the following list of generally accepted principles, concepts, and methods for quantifying and reporting GHG reduction from GHG projects:

1. **Relevance:** Use data, methods, criteria, and assumptions appropriate for the intended use of reported information.
2. **Completeness:** Consider all relevant information that may affect the accounting and quantification of GHG reductions and complete all requirements.
3. **Consistency:** Use data, methods, criteria, and assumptions that allow meaningful and valid comparisons.
4. **Transparency:** Provide clear and sufficient information for reviewers to assess the credibility and reliability of GHG-reduction claims.
5. **Accuracy:** Reduce uncertainties as much as is practical.
6. **Conservativeness:** Use conservative assumptions, values, and procedures when uncertainty is high.

According to WRI/WBCSD, these principles "are intended to underpin all aspects of the accounting, quantification, and reporting of project-based GHG reductions…[and] are derived in part from accepted financial accounting and reporting principles and are largely the same as those that guide the Corporate Accounting and Reporting Standard."[1]

This methodology makes a strict commitment to adhere to these principles. The assumptions and values in the GREET model along with all GHG-quantification methods described have been designed and evaluated to meet the above principles.

[1] https://ghgprotocol.org/corporate-standard

1.6 LCA Tools and Approach

The process of establishing a carbon accounting system includes:

1. Setting a baseline CI value for 1) business-as-usual biogas scenarios against which the benefit of a biogas project is being assessed, and 2) natural gas, grid electricity, and synthetic fertilizer, when the end-product extends beyond biogas (excluding hydrogen). Please see individual chapters for additional information.
2. Performing the life-cycle assessment (LCA) for biogas systems based on standardized assumptions regarding the type of facility and obtaining a CI score for system outputs using the most updated CA-GREET model version. (**Note**: this methodology takes the approach of using CA-GREET as a basis but aims to build on and modify this methodology as appropriate.)
3. Comparing the project's biogas CI with the baseline value and quantifying the GHG reduction based on CI.

The carbon accounting methodology presented here is developed while considering the fundamentals and guidelines of an LCA. An LCA is a comprehensive methodology of assessing a product or process's GHG impact (e.g., CI) over the product's life cycle and supply chain. Developing an LCA follows the ISO's 14040:2006 Environmental Management – Life-cycle assessment – Principles and framework and 14044:2006 Environmental management – Life-cycle assessment – Requirements and guidelines standards.

CI refers to the total measure of GHG emissions involved in producing, distributing, and consuming a product; it is measured in terms of GHGs emitted (calculated in CO_2 equivalent, CO_2e) per unit of energy or mass or another functional unit.[2] This methodology uses two units for reporting the carbon performance of the projects: 1) annual metric tonnes of CO_2e for reporting the carbon footprint of the biogas generated per biogas project, and 2) grams of CO_2e per megajoule (MJ) of fuel (e.g., RNG, compressed natural gas, or CNG, etc.) or grams of CO_2e per kilowatt hour (kWh) (e.g., electricity) depending on the end-use of the biogas in various applications. Adopting two units at various points of the project boundaries allows for more consistent comparison among biogas projects. Using annual metric tonnes of CO_2e as a reporting unit facilitates the comparison among baseline and project emissions and enables estimation of the emission reduction achieved. Using grams (g) of CO_2e per MJ (g CO_2e/MJ) of fuel or grams of CO_2e per kWh (g CO_2e/kWh) helps with comparing the CI of the project with the fossil-based counterpart it replaces at the point of replacement.

This methodology is based on the CA-GREET model, which is based on the full GREET model with some specific adjustments for the California LCFS program. GREET is open access, updated annually, and supported by the U.S. Department of Energy (DOE) and Argonne National Laboratory (ANL). GREET offers a complete picture of the energy and emissions of fuel and other products by considering its full life cycle. LCA calculations in GREET rely on life-cycle inventory data maintained and annually updated by the DOE.

[2] A functional unit is a measurable unit of reference used for comparing the performance of various projects.

The GREET model is widely used by the biogas industry and recognized as the preferred LCA tool to measure GHG emissions and calculate CI scores for RNG projects across the country. The U.S. Environmental Protection Agency (USEPA) uses GREET for clean fuel monitoring. California, Washington, and Oregon, three states with state-specific LCFS programs, use the GREET model as the basis for all CI score calculations.

The development of the GREET model has been supported by several DOE offices since 1995, including the Vehicle Technology Office (VTO), the Bioenergy Technology Office (BETO), the Fuel-Cell Technology Office (FCTO), the Strategic Priorities and Impact Analysis (SPIA), the Advanced Research Projects Agency–Energy (ARPA-E), and the Building Technologies Office (BTO). GREET has been in the public domain and available free of charge since its creation in 1995. Per ANL, examples of major uses of GREET include the following:

1. DOE, the U.S. Department of Agriculture (USDA), and the U.S. Navy use GREET for research and development (R&D) decisions.
2. The USEPA used GREET for the development of the Renewable Fuel Standard (RFS) and vehicle GHG standards.
3. The California Air Resources Board (CARB) developed CA-GREET for its LCFS registration and compliance.
4. The Oregon Department of Environmental Quality (ODEQ) developed OR-GREET for its Clean Fuels Program (CFP) registration and compliance.
5. The U.S. Department of Defense (DoD) Defense Logistics Agency (DLA)-Energy uses GREET for alternative fuel purchase requirements.
6. The International Civil Aviation Organization (ICAO) uses GREET to develop CI for aviation fuel pathways.

GREET includes almost all fuel types and fuel production technologies with some maturity in the market. GREET can model RNG produced from a wide range of project types of animal manure, WWTPs, landfills and food scraps, urban landscaping waste, and other organic waste being the most common. The GREET model includes the entire life cycle from feedstock production, collection, transport, pretreatment, fuel production, and fuel transport, to fuel use in different end-use applications (i.e., boiler, vehicle, and power generation).

This methodology uses standardized approaches to CI calculations. It calculates the CI of a biogas system using standardized additionality requirements, baseline assumptions, and emission factors.

1.6.1 Co-Digestion

Mono-digestion often may encounter challenges due to feedstock characteristics. Anaerobic co-digestion is often used to increase methane production from a low-yielding or difficult-todigest material.[3] Mixed feedstocks must be paired based on their synergistic characteristics and the digester must have additional capacity for co-digestion.

This methodology acknowledges that more biogas projects are considering implementing co-digestion. Developing a calculation tool to include all potential co-digestion systems is complicated since different system boundaries and/or baseline scenarios need to be considered. Applying this methodology to individual feedstock, yielding a CI score for the biomethane from each feedstock, and then combining the results to form a composite CI score is a more straightforward approach. This is the approach adopted by CARB for evaluating some LCFS co-digestion pathway applications.

This approach considers the measurement and/or allocation of certain project parameters, such as process energy and biogas production. Biogas production can be allocated based on biomethane potential testing results, while process energy can be allocated based on biogas production or other factors as deemed reasonable.

1.7 Quantifying GHG Reductions

This protocol accounts for all relevant GHGs, including CO_2, methane (CH_4), and nitrous oxide (N_2O) in the emissions assessment.[4] Although all feedstocks in baseline and project scenarios are sourced from biogenic carbon, biogenic carbon is not accounted for here as it is assumed that the biogenic carbon that enters the system will go back to the atmosphere within 100 years. The life cycle carbon accounting values will be expressed in metric tonnes of CO_2e per year for baseline and project biogas production, and g CO_2e/MJ or g CO_2e/kWh, depending on the final product (please see Section 1.8 for end-use GHG accounting).

GHG emissions for baseline and project scenarios are assessed annually. The reduction in emissions achieved is the difference between the emissions that happened in a baseline scenario or would have happened if a project was not implemented. Once baseline and project emissions are identified and estimated, a subtraction of the project scenario from the baseline scenario will provide the change in emissions. Once the change is established, this can be presented as a lump sum reduction if no fuel is produced or within a calculation to compare the CI to a reference CI to show the improvement of displacing the reference fuel if fuel is produced.

Additionally, it is preferred that the emissions from the supply chain are measured or calculated. In the absence of available data, estimates and general emission factors can be used. The same approach in data collection, however, must be adopted for both baseline and project emissions.

Defining model parameters for estimating the baseline and project scenarios:

$$REi = BEi - PEi$$

[3] https://www.epa.gov/sites/default/files/2014-12/documents/codigestion.pdf

[4] Some exclusions of emissions are explained/justified in further sections.

REi: Reduction in emissions for the reporting period for the year, MT CO_2e/year

BEi: Baseline emissions for the reporting period for the year, MT CO_2e/year

PEi: Project emissions for the reporting period for the year, MT CO_2e/year

All "MTs" throughout this document refer to metric tonne.

1.8 Emission Reductions

Emission reduction can be calculated in one of two ways. The first is a lump sum that represents all the emissions avoided by the project. This applies to situations where no fuel is made in the avoided emission project such as putting gas into a flare that was previously vented to the atmosphere.

Emission Reduction = Baseline Emissions – Project Emissions = Metric Tonnes of CO_2e

When the project does produce fuel, the lump sum is then divided by the energy of the fuel to reach units of CI. This represents the number of emissions generated for each unit of fuel produced.

Metric tonnes of CO_2e/MJ of energy in the fuel (LHV) = CI Score

To generate credits using the CI, the CI of the fuel being replaced is compared to the CI score of the project to determine the improvement and to generate credits. Below is the LCFS methodology:

Credits = $(CI_{reference} / EER^{XD} - CI_{reported}) * E_i * EER^{XD} * C$

Where

$CI_{reference}$ = The CI to be compared for improvement.

EER^{XD} = Dimensionless Energy Economy Ratio relative to the fuel displaced based on the end use of the fuel in LHV.

$CI_{reported}$ = The CI calculated from the difference between baseline and project emissions.

E_i = Energy of the fuel or blendstock in MJ in LHV.

C = Factor used to convert credits to units of metric tonnes from g CO_2e.

1.9 Definitions and Acronyms

Table 1.9.1 below lists applicable definitions for this methodology.

Table 1.9.1: Definitions

Anaerobic Digestion	-	The sequence of processes by which microorganisms break down biodegradable material without oxygen.
Animal Manure	-	Livestock dung and urine.
Biogas	-	A mixture of biogenic gases composed mainly of methane and carbon dioxide (CO_2) produced from the decomposition of organic matter under anaerobic conditions.
Biomethane / RNG	-	Biogas has been upgraded for use in place of fossil natural gas.
Co-Digestion	-	The practice of combining diverse organic materials such as manure, food waste, agricultural residues, fats, etc. in one digester.
Digestate	-	Residue material after the anaerobic digestion of a biodegradable feedstock, including liquid and solid portions.
Digester	-	A closed tank, oxygen-free environment where microorganisms break down organic materials.
Food Waste	-	Pre- and post-consumer waste/food scraps.
Functional Unit	-	A quantitative unit based on the function of a product that provides the reference point based on which the environmental performance of a product, process, or service is measured and reported.
Life-Cycle Assessment	-	Comprehensive methodology of assessing a product or process's environmental impacts.
Other Waste	-	Substance or mix of substances (solid, liquid, or gaseous) discarded after primary use, defective, and of no use (i.e., industrial waste, agricultural waste, yard waste, etc.).
Wastewater	-	Water that has been used in washing, flushing, manufacturing, etc. It is a complex mix that may contain significant concentrations of solids, dissolved and particulate matter, and/or microorganisms, etc.

For this methodology, the following acronyms apply:

AWMS	-	Animal waste management systems
BCS	-	Biogas control system
CAFO	-	Concentrated animal feeding operations
CH_4	-	Methane
CI	-	Carbon intensity
CNG	-	Compressed natural gas
CNMP	-	Comprehensive nutrient management planning
CO_2	-	Carbon dioxide
CO_2e	-	Carbon dioxide equivalent
DOC	-	Degradable organic carbon
EIA	-	Environmental impact assessment
GHG	-	Greenhouse gas
GWP	-	Global warming potential
ISW	-	Industrial solid waste
LCA	-	Life-cycle assessment
LCFS	-	Low-carbon fuel standard
LFG	-	Landfill gas
MSW	-	Municipal solid waste
MT	-	Metric tonne
N_2O/NOX	-	Nitrous oxide
RNG	-	Renewable natural gas
SSR	-	Sources, sinks, and reservoirs
VCM	-	Voluntary carbon market
VVB	-	Validation and verification body
WWTP	-	Wastewater treatment plant

1.10 Biogas Project Definition

This methodology contemplates biogas projects that capture, process, and/or utilize biogas from landfills, wastewater treatment, and recovery plants, animal manure management and storage systems, food waste handling sites, and other waste processing facilities. Greenhouse gases, particularly methane, would have been directly emitted to the atmosphere without the biogas project. Biogas projects capture (and further process/combust) otherwise emitted biogenic methane, and the methodology represents this change. In addition, this methodology provides guidance for digestate utilization/crediting, where applicable.

Applicable uses of the biogas and their attributes are as follows:

- Flaring
- Converting to electricity
- Upgrading to RNG
- Heating

Eligible feedstocks for each project type are described in subsequent sections.

1.11 Associated Methodologies

The table below shows various approved methodologies and protocols related to different biogas project types that were reviewed and used as references to the present methodology.

Table 1.11.1: Related Methodologies and Protocols

Methodology	Overview	Relevance
	American Carbon Registry	
Landfill Gas Destruction and Beneficial Use Projects	Applicable for collection and combustion of landfill gas, located in the U.S.	Considers a six-month start date (CI score is not applied).
	Climate Action Reserve	
U.S. Livestock Project Protocol	Applicable for GHG-emission reductions associated with the installation of a biogas control system (BCS) for manure management on dairy cattle and swine farms in the U.S.	Considers a six-month start date, only dairy cattle and swine are included (CI score is not applied).

Organic Waste Digestion Protocol; Version 2.1	Applicable for on-site destruction by flare or injection into the gas distribution network.	Considers anaerobic digestion of industrial wastewater and livestock manure (CI score is not applied).
U.S. Landfill Protocol; Version 6.0	Applicable for on-site destruction or transported for off-site use/destruction.	Considers only from landfills not subject to regulatory required destruction, non-USEPA bioreactor, and only leachate added to the biomass (CI score is not applied).

Clean Development Mechanism		
Thermal Energy Production with or Without Electricity; Version 22.0, AMS-I.C.	Applicable for thermal energy production that displaces fossil fuel in on-site consumption or consumption at other facilities.	Considers solar, hydro, wind, renewable biomass, and biogas in single, co- and tri-generation (CI score is not applied).
Methane Recovery in Animal Manure Management Systems; Version 21.0, AMS-III.D.	Applicable for destruction by flaring, electricity and heat generation.	Considers only livestock manure and replacing digesters with AWMS can be collected from multiple sources for processing at a centralized facility (CI score is not applied).
Landfill Methane Recovery; Version 10.0, AMS-III.G.	Applicable for destruction by flaring, electricity generation, hydrogen production, and transportation fuel.	Considers MSW, ISW, and other solid wastes containing biodegradable organic matter for biogas capture, but not for those who deliberately boost methane generation compared to the baseline (CI score is not applied).
Methane Recovery in Wastewater Treatment; Version 19.0, AMS-III.H.	Applicable for destruction by flaring, electricity generation, hydrogen production, and transportation fuel.	Considers wastewater and sludge across several treatment systems to recover and combust the biogas (CI score is not applied)
Methane Recovery from Livestock and Manure Management at Households and Small Farms; Version 05.0, AMS-III.R.	Applicable to recovery and destruction systems and the addition of digesters to a management system.	Considers livestock manure and other agricultural wastes in small-scale recovery and destruction systems (CI score is not applied).

Natural Gas Substitution by Biogenic Methane Produced from the Anaerobic Digestion of Organic Waste; Version 01.0, ACM0024	Applicable to RNG replacing natural gas in a distribution grid.	Considers organic waste (excluding hospital waste) treated by anaerobic digestion and upgraded to replace natural gas (CI score is not applied).
Biogenic Methane Injection to a Natural Gas Distribution Grid Version 04.0.0, AM0053	Applicable to RNG replacing natural gas in a distribution grid.	Considers livestock manure, wastewater, and other organic matter (not MSW), and upgraded to replace natural gas (CI score is not applied).
Methodology for Collection, Processing, and Supply of Biogas to End-users for Production of Heat Version 01, AM0075	Applicable to the production of heat and/or electricity.	Considers waste organic matter and the aerobic decomposition of waste matter at landfills and wastewater treatment plants (CI score is not applied).
Mitigation of GHG Emissions with the Treatment of Wastewater in Aerobic Wastewater Treatment Plants, AM0080	Applicable to mitigation of emissions by methane destruction.	Considers wastewater and sludge that replace existing anaerobic open lagoon system (CI score is not applied).

Gold Standard		
GHG Emission Reductions from Manure Management Systems and Municipal Solid Waste; ACM0010 Version 07.0.0	Applicable for on-site destruction by flare, injection into the gas distribution network, or on-site use as a fuel for electricity or heat generation.	Considers only livestock manure and MSW, which can include comingling, composting, and improved AWMS (CI score is not applied).
Methodology for Animal Manure Management and Biogas use for Thermal Energy Generation; Version 1.1	Applicable for on-site destruction by flare, injection into the gas distribution network, or on-site use as a fuel for electricity or heat generation.	Considers livestock manure and agricultural wastes in anaerobic digesters (CI score is not applied).
California LCFS		
Dairy and Swine Manure Biogas to Electricity Pathways	Applicable to dairy and swine manure anaerobic digestion operations.	Only dairy and swine manure are included. Does not assign a credit for replacing fertilizer with digestate. The only LCFS pathway that offers biogas to electricity credit calculations.
Landfill Biomethane Pathway	Applicable to landfill operations.	Does not include additional avoided methane credits if a landfill demonstrates a higher landfill gas collection efficiency than previously predetermined by the USEPA.
Wastewater Sludge Biomethane Pathway	Applicable to anaerobic digestion of wastewater sludge operations.	Does not include credit for diverting biosolids from landfills.

LCFS Overall	Applicable to RNG (biomethane) and offers Tier 1 calculator for biomethane from landfills, wastewater sludge, organic waste, and dairy and swine manure.	Does not include any credit for non-transportation end uses. Has an eligibility cut-off date that apply for earning avoided emissions credit. Has a policy factor to inflate the biogas CI when fossil-based NG/diesel/propane are used for processing.

2.0 Project Proponent

Project proponents should provide detailed information according to the list below. Note that this list is not exhaustive, and proponents should refer to their specific project section for additional information requirements.

- Key contacts responsible for the project operation and crediting, including names, titles, and contact information.
- Location of the project facility.
- Ownership details.
- Partner organizations and stakeholders with a brief description of their rights to influence the project's vital activities, if any.
- Details of utilities associated with the project (i.e., electricity, natural gas, water, wastewater, garbage, etc.).
- The launch date of project activities, including the start of construction and commissioning.
- Project's active period regarding continuous methane destruction.
- Timeline or chronology for the project.
- Monitoring frequency in each phase of the process.
- If monitoring or part of it is being implemented by the third-party service provider, please provide a brief breakdown (i.e., entity, services, frequency, etc.).
- Targeted feedstock, end uses, and co-products.
- Customers and users with a brief description of their rights to influence the project's vital activities, if any.
- Information on the regulations under which the project operates, including permits obtained (planned).

2.1 Pathway to a Crediting Program

To qualify under this methodology, projects should comply with the eligibility criteria provided below and each project should conform to specific eligibility requirements provided in subsequent sections that are focused on certain project types.

The project eligibility criteria stated in this methodology are complimentary of any additional requirements specified by the regulatory party or standard that the project expects to apply. In any case of conflicting rule(s), the regulatory guidelines shall prevail.

2.1.1 Location

Only projects located in the U.S., its territories, and U.S. tribal lands are eligible under this methodology. The project location must be provided using geolocation polygons to describe project characteristics accurately and to demonstrate a project's conformance regarding ownership and regulation.

2.1.2 Start Date

The project start date is the date on which the project became operational and began GHG emission reductions. For this methodology, a project is fully operational when methane is continuously destroyed/utilized after a start-up period, which may be a maximum of two years after the date of project commissioning. Project commissioning is the first day in which the BCS or respective destruction devices are fully operational and either destroying or enhancing biogas.

Projects must complete validation within the start-up period. The start-up period is the period that begins at the initial synchronization (commissioning of all systems, testing, and calibration) and ends at the commercial operation date.

2.1.3 Crediting Period

The project crediting period is the time during which GHG emission-reduction credits generated by the project are eligible for issuance. Project developers can issue GHG-reduction credits under this methodology for 10 years after the project's start date. All projects that pass the applicability conditions in this methodology and continue to prove performance annually may generate GHG-reduction credits for the project's first crediting period (10 years).

Project crediting periods can be renewed to ensure that changes to a project's baseline scenario and regulatory surplus (as defined in the next section below) are considered throughout the project's lifetime. Project developers may apply for renewal of the crediting period twice up to 30 years in total. Project developers must apply for renewal within the final six months of each crediting period. The crediting period can start at any time during the calendar year.

2.2 Additionality

To qualify under this methodology, projects should generate GHG reductions that are additional to what would have otherwise occurred. The project developer must demonstrate that reductions are above and beyond the business-as-usual scenario and would not have occurred in the absence of the biogas system.

Project developers may satisfy the additionality eligibility by passing two tests:

2.2.1 Regulatory Test

The project shall demonstrate regulatory surplus at validation and each project crediting period renewal. Proponents demonstrate regulatory surplus by ensuring that project activities are not mandated by any law, statute, or other regulatory framework.

If at any time project activities become required by regulations/law, the project may continue to generate credits only until the end of the current crediting period and it will fail to demonstrate additionality for crediting period renewal.

2.2.2 Performance Test

In addition to regulatory surplus, the performance test will be defined by the registry that will generate credits via this framework. This will ensure that project activities are additional compared to the baseline scenario based on the industry's common practice, statistics, etc.

Projects pass the performance test by meeting a performance threshold established on an ex-ante basis. The performance threshold is above the business-as-usual scenario. If the project meets the threshold, then it exceeds what would happen under the business-as-usual scenario and generates additional GHG reductions. BCS installation is the initial minimum requirement, and further project developers must consult with specific registries to ensure compliance with additional requirements for certain project types, so the additionality of the project will be in accordance with the applicable performance standards.

Project proponents should consult with the specific registry that they are aiming to generate credits through regarding the performance threshold for certain project types. If the project meets the eligibility requirements, including the performance threshold, it will be eligible to register credits via this methodology. If the project proponent wishes to apply for crediting-period renewal, the project must meet the eligibility requirements of the most current version of this methodology at the time of the submittal for crediting-period renewal.

3.0 Project Monitoring Recommendations

3.1 Quantification Methods and Accuracy

The impacts of project activities on relevant emission sources, sinks, and reservoirs (SSR) must be monitored to determine the net GHG benefit. For those purposes, a monitoring plan shall be established for all monitoring and reporting activities associated with the project by the project proponent. The monitoring plan will serve as the basis for verification bodies to confirm that the monitoring and reporting requirements have been, and will continue to be met, and is ongoing at the project site. The monitoring plan must cover all aspects of monitoring and reporting contained in this methodology and specify how data is collected, recorded, protected, and retained. The monitoring plan shall provide:

- Parameters to be monitored and details (i.e., units, description, acquisition frequency).
- The frequency of instrument field checks, calibration activities, and data acquisition.
- The role of individuals performing each specific monitoring activity.
- The details about the data management system and the flow of raw data to the final report.
- The process of BCS activities, digestate separation, and end use (animal manure digestion only).
- The usage of fossil fuels for project activities.
- Electricity usage.
- The equipment and frequency of gas generation and methane-content recording.

Table 3.0.1 below provides the list of relevant parameters to be monitored under this methodology with respect to the applicable project type.

Table 3.0.1: Relevant Monitoring Parameters

Parameter	Unit	Value	Description	Frequency	Calculated (C), Measured (M), Reference (R)	Comments	Applicable Project Type
$PE_{CH4, BCS}$	tCH4		Methane emissions from the BCS	Monthly	M, C		All
R	cal/Kmol		Ideal gas constant	Continuous, weekly, monthly, as required	R		All
ELC_{P}	kWh		Electricity used in the project scenario	Monthly	M	Utility bills (each grid will need its utility bill)	All
F_{bg}	m^3/day		Biogas flow	Daily	M	Continuous flow meters	All
CH_4 content	percentage		Methane content of gas flow	Continuous, weekly, monthly, as required	M	Measure of raw biogas % before upgrading	All
$PE_{CH4, BCS}$	tCH4		Methane emissions from the BCS	Monthly	M, C		All
GWP_{CH4}	tCO_2e/tCH_4	28	Global warming potential (GWP) of methane for 100 years	Monthly	C	IPCC 6th Assessment Report	All
OX	-	0, 0.1	The factor for the oxidation of methane by soil bacteria	Uncertain	C	Equal to 0.10 for all landfills except those that incorporate a	Landfill

						synthetic liner throughout the entire area of the final cover system where OX = 0	
FF_P	volume		Fossil fuels used in project scenario	Monthly	M	Utility bill	Landfill
F_{LFG}	Scfm		Landfill gas flow	Continuous (≤15 minutes)	M	Meter #	Landfill
$CH4_{LFG}$	%		Landfill gas methane content	Continuous[1] (≤15 minutes)	M	Meter #	Landfill
VS_L	kg/animal /day)		Daily volatile solid production for each livestock category	Daily	C		Animal Manure Digestion

Flow meters, sampling devices, and gas analyzers shall be subject to regular maintenance, testing, and calibration to ensure accuracy according to regulatory required frequency and manufacturer's recommendations. Relevant parameters shall be monitored as indicated in Table 3.0.1 above.

An important coefficient in the conversion of non-CO_2 gases into CO_2 equivalent quantification is Global Warming Potential (GWP), which converts non-CO_2 gases into CO_2 equivalent. GWP is a measure of the relative radiative effect of a given GHG compared to another, integrated over a chosen time horizon. It is the industry's commonly adopted practice to use a 100-year time horizon (e.g., USEPA's GHG Reporting Program, National GHG Inventory Reporting under UNFCCC, Clean Development Mechanism, CA-LCFS, Climate Action Reserve, etc.). For this methodology, project proponents should use GWP100 values provided in the IPCC 6th Assessment Report[5] for CH_4, N_2O, and other relevant non-CO_2 gases.

3.2 Record-Keeping

For independent verification and historical documentation, project developers must keep all information outlined in this methodology for 10 years after it is generated. This information will not be publicly available but may be requested by the verifier. System information the project developer must retain includes:

- Data inputs for GHG-reduction assessments.
- Copies of all permits relevant to project activities.
- Biogas flow meter information, including model number, serial number, calibration procedures, etc.
- Methane monitoring information.
- Destruction device monitoring information.
- Calibration results for all meters.
- Biogas flow and methane content data.
- Feedstock data.
- Results of CO_2e reduction calculations.
- Initial and subsequent verification records and results.
- Maintenance records of the BCS and monitoring equipment.

3.3 Validation/Verification

To validate and verify any of the projects using the current methodology, the validation and verification body (VVB) must have a valid accreditation under ISO 14065:2020 General principles and requirements for bodies validating and verifying environmental information certified by ANSI National Accreditation Board (ANAB) under the sectorial scope defined as *Waste Handling and Disposal*.[6]

[5] https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Chapter_07_Supplementary_Material.pdf#page=27.

[6] ANSI National Accreditation Board (2023), VV-FR-704 ANAB Application for Accreditation for Greenhouse Gas Validation/Verification Bodies – 6. Activities and Sector Groups included in this Application for Accreditation.

3.4 Project Risks

SSR within boundaries (political, physical, social, regulatory, etc.) are the most notable project risks across the project types. With regards to anaerobic digester lagoon fugitive emissions, there can be several causes, including the following:

- **Poor Design and Construction:** If the lagoon is not designed and constructed properly, it may be more prone to leaks. This includes using poor-quality materials, not designing the lagoon to be leak-tight, and not installing monitoring and alarm systems to detect leaks.
- **Operational Problems:** If the lagoon is not operated properly, it may be more prone to leaks. This includes not regularly inspecting the lagoon for leaks, repairing any leaks found, and not following good operational practices.
- **Natural Factors:** Natural factors, such as earthquakes, floods, and extreme weather events, can also cause anaerobic digester lagoons to leak.

The following are ways to mitigate fugitive emissions from anaerobic digester lagoons.

- **Use High-Quality Materials:** The lagoon should be constructed using high-quality materials that are resistant to corrosion and degradation.
- **Design the Lagoon to be Leak-Tight:** The lagoon should be designed with a double-wall construction or other features that make it difficult for leaks to occur.
- **Install Monitoring and Alarm Systems:** The lagoon should be equipped with monitoring and alarm systems that can detect leaks early on.
- **Regularly Inspect the Lagoon for Leaks:** The lagoon should be inspected regularly for leaks, both visually and using non-destructive testing methods.
- **Repair any Leaks Found:** Any leaks found should be repaired promptly.
- **Follow Good Operational Practices:** The lagoon should be operated in accordance with good operational practices, such as avoiding overloading the lagoon and maintaining proper pH levels.
- **Take Steps to Protect the Lagoon from Natural Factors:** The lagoon should be in an area that is not prone to earthquakes, floods, or extreme weather events. If the lagoon is in an area that is prone to these events, steps should be taken to protect the lagoon, such as installing floodwalls or other protective measures.

4.0 Communication with the Public

Considering environmental justice during project development promotes stakeholder trust. Community engagement is an opportunity to provide and receive feedback on technological information and ecosystem impacts. Stakeholder discussion and feedback may also help project developers identify problems that they might have missed during their project conception and early planning phases.

Having a good understanding of community norms, dynamics, and sentiment will boost the successful implementation and operation of the project. This understanding can be achieved by continuous engagement with people. It could be done by setting up a public feedback system. This system could also be used to address any inconveniences stakeholders might face at any point during a project's life.

Project developers are encouraged to invite stakeholders' feedback from the early stages of a project irrespective of prevailing regulations.

5.0 Animal Manure Digestion

5.1 Definition

This category includes baseline and projects that handle animal manure. The definition of animal manure and what feedstock fall under this category can be found in Table 5.1.1.

Table 5.1.1: Definition of Eligible Sources Under the Category of "Animal Manure Digestion"

Animal	Livestock Types	Typical Manure Management
Beef Cattle	Steer, bull, ox, calves, yearlings	Liquid-based systems (anaerobic lagoon), dry lot, composting, bedding.
Dairy Cow	Milkers, dry, heifers, calves	Liquid-based systems (anaerobic lagoon), dry lot, composting, and bedding.
Poultry	Layers, broilers	Liquid-based systems, deep bedding, dry lot, and composting.
Swine	Breeding swine (sows), growing swine (finishers), nursery swine	Liquid-based systems (anaerobic lagoon, deep pit), dry lot, composting, and bedding.
Other (to acknowledge there may be unique projects that can be looked at on a case-by-case basis).	Various types	Dependent on the animal source selected.

This methodology applies to project activities that divert manure to an anaerobic digester, and then produce, process, and utilize biogas from projects.

Animal manure digestion involves the diversion of animal manure from current manure management practices to an anaerobic digester. Projects that are applicable under this methodology/module are:

- Existing livestock facilities that manage manure with the addition or expansion of biogas production and/or capture.
- The refurbishment of BCS facilities that would have been decommissioned without the project (must be proven to be at the end of life).

These projects are not applicable under the following conditions:

- Other livestock types are currently not mentioned in Table 5.1.1 above.
- Efficiency improvement projects.
- Upgrades are to existing facilities that are not at risk of decommissioning.
- Changes in operational practices leading to improved biogas capture.

All GHG sources and SSRs included or excluded from the project boundary are shown in Table 5.2.1.

5.2 Overall Boundary

During animal manure project activities biogas/RNG is produced, processed, and utilized accordingly. Digester effluent (digestate) is routed to certain end-uses. The project boundary then includes the physical, geographical site(s) of:

- Animal manure management systems.
- Facilities that recover/flare/combust/use methane.
- Digestate fate.

The system boundary diagram is provided below.

Figure 5.2.1: System Boundary for Animal Manure Scenarios

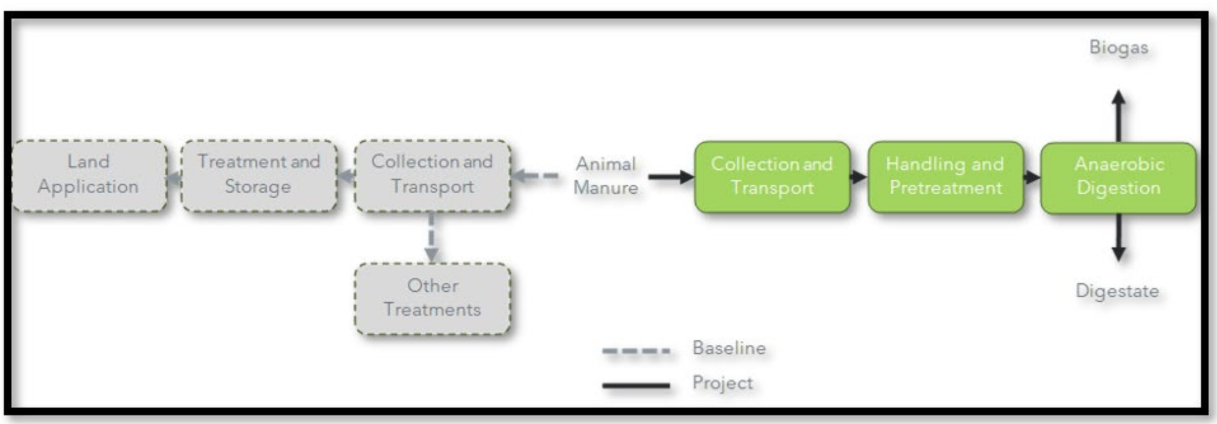


Table 5.2.1: GHG SSRs Included or Excluded from the Project Boundary

SSR	Gas	Baseline (B), Project (P)	Included, Excluded	Justification
Electricity Consumption	CO_2, CH_4, N_2O	B, P	Included	Electricity may be consumed from the grid or generated onsite in the baseline and project scenarios for various purposes, including manure handling and pretreatment.
Fuel Consumption	CO_2, CH_4, N_2O	B, P	Included	
Mobile and Stationary Support Equipment	CO_2	B, P	Included	If any additional vehicles or equipment is required by the project beyond the baseline, emissions from such sources shall be accounted for.
Manure Treatment Process	CO_2	B	Excluded	CO_2 is biogenic.
	CH_4, N_2O	B	Included	
Digestate Fate Emissions	CH_4, N_20	P	Included	Emissions related to digestate use such as bedding, fertilizer, or anaerobic storage.
Enteric Fermentation	CH_4	B, P	Excluded	Livestock operations should not change their feeding strategy to maximize biogas production from a digester.

Mechanical Systems Used to Collect and Transport Waste	CO_2	B, P	Included	Emissions from any additional vehicle or equipment used shall be accounted for.
	CH_4, N_2O	B, P	Excluded	The emission source is assumed to be very small.
Combustion During Flaring, Electricity, and Heat Generation, Including Incomplete Combustion of Biogas	CH_4	P	Included	The primary source of emissions from project activities.
	CO_2, N_2O	P	Excluded	CO_2 is biogenic, and N_2O is assumed to be very small due to it being a reactive intermediate.

For CARB LCFS projects, the current regulations only allow dairy and swine manure to be grouped into certain categories. For LCFS dairy projects, the following herd types are considered with the specific diet indicated in parenthesis: Dairy Cows (on feed), Non-milking Dairy Cows (on feed), Heifers (on feed), Calves (grazing), Bulls (grazing), Heifers (grazing), and Adult Cows (grazing). Similarly, for swine projects, the following herd types are considered: Nursery Swine, Grow/Finish Swine, and Breeding Swine.

Animal manure that could additionally be considered in the voluntary market could be beef cattle, poultry, sheep, goats, etc.

5.3 Baseline Emissions (Fugitive)

Baseline emissions are considered from a manure management standpoint. These emissions result from the manure degrading either anaerobically or aerobically without the project activities. Anaerobic degradation is when the volatile solids are in a system without oxygen. This can occur when the manure has at least three feet of water above it as in the uncovered anaerobic lagoon, or there is a barrier preventing the transfer of oxygen as with a natural crust cover. Manure can also degrade aerobically or within the presence of oxygen. This can occur in many ways such as lying in a pasture, collecting, and spreading on a field or storing.

Each of these manure management processes, both anaerobically and aerobically, has factors associated with the emissions produced. The following are examples taken from the CARB LCFS program:[7]

1. Anaerobic
    a. Uncovered anaerobic lagoon
    b. Liquid/slurry uncovered
    c. Liquid/slurry with natural crust cover
2. Aerobic
    a. Pasture, range, and/or paddock
    b. Daily spread
    c. Solid storage
        i. Dry lot
        ii. Pit storage below animal confinements (<1 month)
        iii. Pit storage below animal confinements (>1 month)
        iv. Cattle and swine deep bedding (<1 month)
        v. Cattle and swine deep bedding (>1 month)
        vi. Composting
            1. In-vessel or static pile
        vii. Composting
            1. Passive or intensive windrow
        viii. Aerobic treatment
        ix. Burned for fuel

In the baseline, there are energy inputs needed for manure collection and management. If the change in manure management practices is negligible from the baseline to the project, it is assumed that no net emissions occur from these activities. From this assumption, the system boundary can exclude the manure management practices and instead begin at the manure collection.

Baseline emissions are then calculated as follows:

$BE = \sum BE_{MMP} + BE_{energy} + BE_{uncollected}$

BE_{MMP} = Manure emissions related to the management practices of each herd type.

BE_{energy} = Energy emissions for manure management.

$BE_{uncollected}$ = Manure emissions of uncollected or unmanaged manure.

5.4 Project Emissions

Project emissions are actual GHG emissions that occur within the LCA boundary after the installation of the BCS due to the energy demands of the project equipment. Project emissions are calculated on an annual, ex-post basis. Project emissions are to be tracked

[7] https://ww2.arb.ca.gov/our-work/programs/low-carbon-fuel-standard

diligently, either through invoices, receipts, direct measurements, or by incorporating recognized emission factors where direct data is not available.

Fugitive methane emissions are estimated based on both modeled and metered data. For greenfield projects that are not fully commissioned yet, assessment will be done based on the modeling. For already commissioned projects, fugitive emissions shall be estimated based on the metered data (i.e., methane flows are measured at different points, and assessment/calculation is performed based on the actual data). However, for commissioned projects, it is also possible to perform estimations of fugitive emissions via modeling instead of metered data.

For the sake of conservativeness, this methodology encourages project proponents to estimate fugitive emissions via both approaches (modeling, metered plus calculated), and select the maximum value of both results.

$$FE = Max\ (FE_{met}, FE_{mod})$$

Methane emissions from manure storage and/or treatment systems other than the BCS are modeled.

Project emissions include:

- Any methane created by the BCS that is not captured and/or destroyed by the control system, if it is not measured, is considered fugitive.
- The GHGs from the digester effluent treatment systems (if any).
- The physical leakage of biogas in the manure management systems, which includes the production, collection, and transport of biogas to the point of flaring/combustion or gainful use, including pipelines.
- The CO_2, CH_4, and N_2O emissions from electricity consumption and mobile and stationary combustion sources resulting from project activity during the reporting period.

In the project, there are also emissions related to the digestate management system post-digester. Digestate has a few common fates: anaerobic lagoon storage, land application, and solid storage. For anaerobic lagoon storage, digestate is stored in lagoons to reduce the smell and to provide easily spread fertilizer for the farm. To be considered anaerobic, the manure must have at least three feet of water above it with no aeration or agitation. This then creates the conditions for methane to be generated in the system. Land application is what is considered when the digestate is spread on the ground for further decomposition, either by straight land application or composting. Solid storage is when digestate is collected and stacked for further management but spends most of the decomposition stage in large piles. This is common when the digestate is eventually used as bedding.

The CI is calculated as a comparison between the emissions from the baseline and the project. The following combines the baseline formulas earlier to calculate the CI score of the project.

$$PE = \sum PE_{MMP} + PE_{energy} + PE_{uncollected}$$

PE_{MMP} = Emissions related to the anaerobic digestion of manure for each herd type.

PE_{energy} = Energy emissions for manure management, digester operation, and upgrading facility.

$PE_{uncollected}$ = Manure emissions of uncollected or unmanaged manure.

The CI is then calculated as the difference between the baseline and project CI.

5.5 Notable Differences from CA-GREET

For biogas from animal manure digestion, CA-LCFS and CA-GREET currently only allow for dairy and swine manure to be considered. This methodology expands the eligible feedstock for digestion to include poultry manure, beef, and potentially other animal manure.

Also, CA-LCFS does not provide credit for using digestate as a fertilizer. This methodology, however, offers the option of taking credit for using digestate as a value-added product, including using it for fertilizer.

6.0 Landfill

6.1 Definition

This category includes projects at landfills that capture landfill gas (LFG) from the anaerobic decomposition of municipal solid waste (MSW). LFG collected from industrial and hazardous waste landfills is ineligible.

Table 6.1.1: Definition of Eligible Sources Under the Category of "Municipal Solid Waste" per USEPA

Eligible Waste Type	Description
Solid-Phase Household Waste	Material discarded by single and multiple residential dwellings, hotels, motels, and other similar permanent or temporary housing establishments or facilities including yard waste, refuse-derived fuel, and motor vehicle maintenance materials.
Commercial and Retail Waste	Material discarded by stores, offices, restaurants, warehouses, nonmanufacturing activities at industrial facilities, and other similar establishments or facilities including yard waste, refuse-derived fuel, and motor vehicle maintenance materials.
Institutional Waste	Material discarded by schools, nonmedical waste discarded by hospitals, material discarded by nonmanufacturing activities at prisons and government facilities, and material discarded by other similar establishments or facilities including yard waste, refuse-derived fuel, and motor vehicle maintenance materials.

Insofar as there is separate collection, processing, and disposal of industrial source waste streams consisting of used oil, wood pallets, construction, renovation, and demolition wastes (which includes, but is not limited to, railroad ties and telephone poles), paper, clean wood, plastics, industrial process or manufacturing wastes, medical waste, motor vehicle parts or vehicle fluff, or used tires that do not contain hazardous waste identified or listed under 42 U.S.C. §6921, such wastes are not MSW. However, such wastes qualify as MSW where they are collected with other MSW or are otherwise combined with other MSW for processing and/or disposal.

Collected LFG must be destroyed either onsite or otherwise processed and repurposed for beneficial use that will result in the effective destruction of the methane by combustion to produce CO_2 and water vapor. Destruction technologies are typically but not restricted to the following:

- Combusted in an open or enclosed flare onsite.[8]
- Combusted for fuel in an engine, turbine, or boiler onsite.[9]
- Upgraded and injected into a natural gas distribution network.
- Upgraded and combusted for fuel in fleet vehicles.

Evidence of operational status can include but is not limited to:

a) Devices equipped with a safety shut-off valve to prevent LFG flow when the device is non-operational may demonstrate the presence and operability of the valve.

b) Devices that rely on the difference between the ambient air temperature and thermocouple reading as evidence that the device is operational must demonstrate a relative temperature difference of 94°C or greater.

Projects are not applicable under the following conditions:

- Projects located at landfills that recirculate leachate.
- Projects that are located at bioreactor landfills, as defined by the USEPA: "An MSW landfill or portion of an MSW landfill where any liquid other than leachate (leachate includes landfill gas condensate) is added in a controlled fashion into the waste mass (often in combination with recirculating leachate) to reach a minimum average moisture content of at least 40% by weight to accelerate or enhance the anaerobic (without oxygen) biodegradation of the waste."
- Projects that deliberately change solid waste management to increase methane generation compared to conditions before the project activity. Example:
    a) Project landfill starts reducing recycling operations for organic waste for no other reason when compared to conditions before the implementation of the project activity.

6.2 Overall Boundary

The project boundary includes the physical and geographical site(s) of the project activity. System boundaries indicate the GHG SSR that must be included in a project assessment. Here, we adopt a gate-to-grave system boundary for biogas production. This means any GHG emissions associated with the collection, transportation, and processing (e.g., size reduction, digestion) of the landfill to biogas, downstream transportation of biogas, as well as end-use activities (if biogas is not upgraded for electricity and transportation fuel), must be included within the system boundaries of the biogas production (Figure 6.2.1). For end-use applications and system boundaries, please refer to Appendix A.

[8] Flares are considered operational (effectively destroying methane) at thermocouple readings of 260°C or greater.
[9] Projects that use LFG for beneficial use shall determine the means to demonstrate that the destruction device was operational, which shall be subject to verifier review.

Figure 6.2.1 - General System Boundary for Landfill Baseline and Project Scenarios

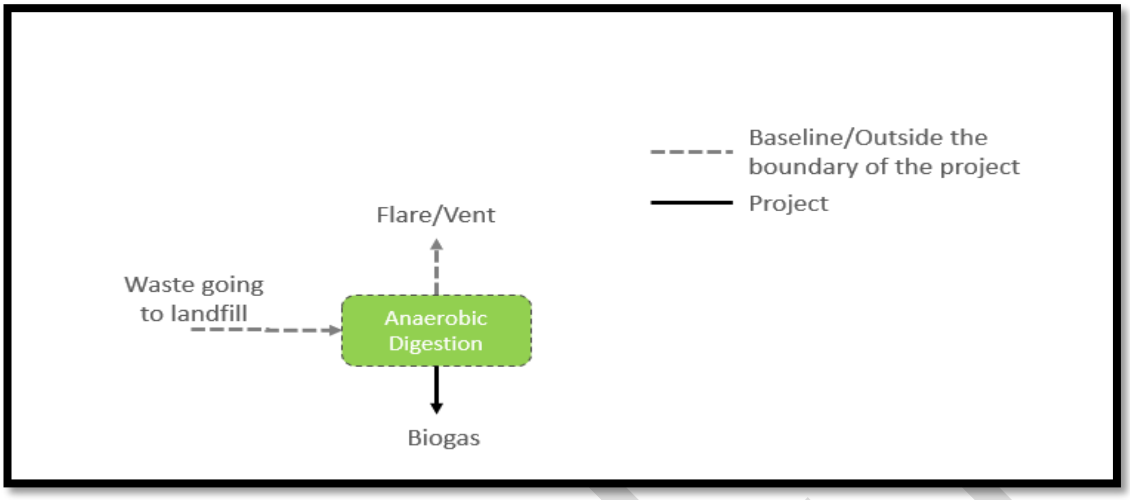


Table 6.2.1: GHG SSRs Included or Excluded from the Project Boundary

SSR	Emission Source	Gas	Baseline (B), Project (P)	Included/ Excluded	Justification
Feedstock Production	Fossil fuel consumption	CO_2, CH_4, N_2O	B	Excluded	Landfill biogas is assumed to be captured using similar methods from the baseline to the project.
Feedstock Collection	Fossil fuel consumption	CO_2, CH_4, N_2O	B	Excluded	Landfill biogas is assumed to be captured using similar methods from baseline to the project.
Feedstock Transportation	Fossil fuel consumption	CO_2, CH_4, N_2O	B, P	Included	Landfill biogas is assumed to be captured using similar methods from baseline to the project.
Feedstock Treatment	Electricity consumption	CO_2, CH_4, N_2O	P	Included	Electricity consumed to process feedstock under project activity.
Feedstock Treatment	Fossil fuel consumption	CO_2, CH_4, N_2O	P	Included	Quantity of fossil fuels consumed to treat feedstock under project activity.

6.3 Baseline Emissions (Fugitive)

The baseline scenario for this project is when the landfill is operating and collecting biogas with the biogas flared and not upgraded. This will be a business-as-usual scenario when no changes to the existing system are made to convert waste to biogas.

Landfill GHG emissions in the baseline are assumed to be the same as the project based on the assumption that modern-day landfills have a gas collection system in place. These collection systems are usually required by state or federal agencies and these requirements invalidate additionality from baseline to project emissions. However, some certain markets and projects would allow the baseline emissions to be quantified, as shown below.

To calculate the baseline emissions, quantifying the degradation of waste from the area and depth of the landfill, and ground emissions from gas composition and flow rate per unit area can be used. The method of obtaining the ground emissions would then be based on analytical testing. If the landfill does not collect gas in the baseline or does not collect it as efficiently in the baseline compared to the project, the reduction in the landfill emissions from the baseline and project can be considered as avoided emissions. This can be simplified to avoid emissions based on the LFG captured in the case of no prior collection system or the improvement in LFG captured in the case of an efficiency improvement effort for an existing gas capture unit. In the absence of any available measured or calculated data, estimates and general emission factors can be used.

An example is the emissions associated with the degradation of waste, which can be estimated either 1) based on the composition of the waste and method of degradation (e.g., in the open fields, composted, or in a landfill), or 2) using average degradation emission factors if composition for a specific waste is not available.

Baseline emissions are then calculated as follows:

$BE_i = BE_{CO2,}\ i + (GWP_{CH4} * BE_{CH4,i}) + (GWP_{N2O} * BE_{N2O,i})$

$BE_{CO2,I} = WM * EF_{CO2}$

$BE_{CH4,I} = WM * DOC * MW_{CH4}/MW_C$ * Model uncertainty factor

$BE_{N2O,I} = WM * EF_{N2O}$

Where:

$BE_{CO2,i}$: Baseline CO_2 emissions (MT CO_2)

$BE_{CH4,i}$: Baseline CH_4 emissions (MT CH_4)

$BE_{N2O,i}$: Baseline N_2O emissions (MT CH_4)

WM: Mass of the waste (MT)

MW: Molecular Weight. The molecular weight of CH_4 ($MWCH_4$) is 16 and the molecular weight of carbon (MWC) is 12.

EFCO2: The emission factor for CO_2 emission from the landfill.

EFN2O: The emission factor for N_2O emission from the landfill.

GWPCH4: Global warming potential of CH_4.

GWPN2O: Global warming potential of N_2O.

Global warming potentials (GWPs) for CH_4 and N_2O are adopted from the latest IPCC report. GWPs for both baseline and project emissions, however, must be selected from the same IPCC report. IPCC AR6 reports 29.8 for CH_4 of fossil origin, 27.2 for CH_4 of non-fossil origin, and 273 for N_2O GWPs.

6.4 Project Emissions

Project emissions include all direct and indirect emissions that occur as a part of the project during the project activities for each year in the monitoring period. These include:

- Direct emissions from activities.
- Indirect emissions from consumption of energy (e.g., electricity, natural gas) and materials.

The project emissions are then calculated as:

$PEi = PE_{CO2,\, i} + (GWP_{CH4} * PE_{CH4,i}) + (GWP_{N2O} * PE_{N2O,i})$

PEi: Project emissions for the reporting period, MT CO_2e/year.

Discontinuous methane monitoring may be conducted under limited circumstances for up to one week with a 10% discount.

6.5 Notable Differences from CA-GREET

The main difference between this methodology and the CA-GREET methodology is the additionality of the capture of LFG. CA-GREET assumes that the landfills are already subjected to regulations that require gas capture at the facility. This methodology outlines how to consider baseline landfill emissions from facilities not capturing the LFG emissions or want to improve the efficiency of the LFG collection unit.

7.0 Wastewater Treatment Plants (WWTPs)

7.1 Definition

This category includes baseline and projects that treat wastewater at WWTPs. The definition of WWTP and what feedstock falls under this category can be found in Table 7.1.1.

Table 7.1.1: Definition of Eligible Sources Under the Category of Wastewater Treatment

Eligible Source Type	Description
Raw Sludge	Untreated sludge.
Activated Sludge	The result from a biological wastewater treatment process in which a mixture of the wastewater and activated sludge (biomass) is aerated in a reactor basin or aeration tank.[10]
Fecal Sludge	Sludge specific to human waste.
Industrial Wastewater	Wastewater discharged from industrial and commercial sources.[11]

This methodology applies to project activities that divert wastewater to an anaerobic digester, and then produce, process, and utilize biogas from the project. Projects that are applicable under this methodology/module are:

- Anaerobic lagoons and ponds with a depth greater than 1.5 meters in an annual arithmetic average.
- Digester with subsequent biogas capture and flaring or utilization of electricity or heat generation.
- Wastewater treatment as in the baseline, but with an added anaerobic digester for the sludge either in the primary or secondary settler.

7.2 Overall Boundary

For wastewater treatment systems using CARB LCFS methodology, the baseline boundary usually begins at the digester based on the assumption that business-as-usual treatment facilities already include or are required to have an anaerobic digester. Figure 7.2.1 shows tanks and ponds in use before project startup could be considered for baseline emissions in a voluntary market program. Here, we adopt a gate-to-grave system boundary for biogas production, where the gate is the anaerobic digestion. Any GHG emissions associated with the collection and purification of the produced biogas, downstream transportation of biogas, as well as end-use activities (if biogas is not upgraded for electricity and transportation fuel),

[10] https://www.epa.gov/system/files/documents/2022-03/wwtpslides-20211021.pdf
[11] https://www.epa.gov/npdes/industrial-wastewater

must be included within the system boundaries of the biogas production (Figure 7.2.1). For end-use applications and system boundaries, please refer to Appendix A.

In the CARB LCFS program, emissions-related digestate and digestate end uses are not considered but could be for certain voluntary programs.

Figure 7.2.1: General System Boundary for Wastewater Sludge Digestion Baseline and Project Scenarios

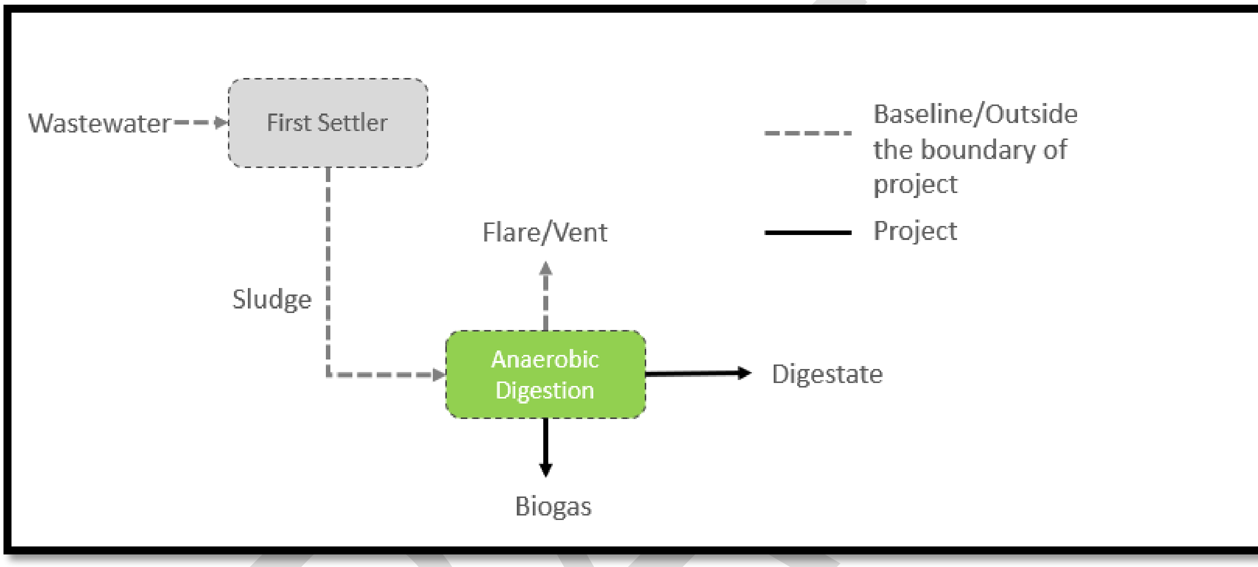


Table 7.2.1: GHG SSRs Included or Excluded from the Project Boundary

SSR	Emission Source	Gas	Baseline (B), Project (P)	Included/Excluded	Justification
Feedstock Production	Fossil fuel consumption	CO_2, CH_4, N_2O	B, P	Excluded	Wastewater treatment is assumed to be sourced from the same location in the baseline and project.
Feedstock Collection	Fossil fuel consumption	CO_2, CH_4, N_2O	B, P	Excluded	Emissions related to the collection of the feedstock are assumed to be similar from baseline to project.
Feedstock Transportation	Fossil fuel consumption	CO_2, CH_4, N_2O	B, P	Excluded	Wastewater treatment is assumed to be sourced from the same location in the baseline and project.
Feedstock Treatment	Electricity consumption	CO_2, CH_4, N_2O	B, P	Included	The change in the treatment process is included from the baseline to the project.
Feedstock Treatment	Fossil fuel consumption	CO_2, CH_4, N_2O	B, P	Included	The change in the treatment process is

					included from the baseline to the project.
Product Related – Transportation of Final Product	Electricity consumption, fugitive loss	CO_2, CH_4, N_20	P	Included	The emissions related to the transportation and injection of the upgraded RNG in the project.

7.3 Baseline Emissions (Fugitive)

Any sort of wastewater treatment system coupled with biogas recovery equipment in the baseline shall be excluded from the baseline emission calculations.

Baseline emissions affected by the project activity may consist of, but not limited to:

i. The GHG emissions produced by electricity or fossil fuels.

ii. The fugitive methane emissions from baseline wastewater treatment systems.

iii. The fugitive methane emissions from baseline sludge treatment systems.

$$BE_y = BE_{p,y} + BW_{WCH4,y} + BE_{SCH4,y} - MR_y$$

Whereas:

BE_y: Baseline emissions in year y (MT CO_2e).

$BE_{p,y}$: Baseline emissions from electricity or fuel combustion in year y (MT CO_2e).

$BE_{WCH4,y}$: Baseline emissions of the fugitive methane from wastewater treatment systems affected by the project activity in year y (MT CO_2e).

$BE_{SCH4,y}$: Baseline emissions of the fugitive methane from sludge treatment affected by the project activity in year y MT CO_2e).

MRy: Amount of methane that would have to be captured and combusted in year y to comply with the prevailing regulations, if applicable.

For voluntary programs, the above methodology could be applied to calculate the change in emissions from baseline to project due to emissions from the holding pond. An additional baseline emission reduction could come in the form of comparing the inputs required to clean the baseline wastewater stream, such as chemicals and process energy, to the digester effluent as some of the required cleanup would be avoided due to anaerobic digestion.

For wastewater treatment systems using CARB LCFS methodology, the baseline boundary usually begins at the digester based on the assumption that business-as-usual treatment facilities already include or are required to have an anaerobic digester. The current baseline assumption for CARB is that the digester is operational, and all the produced biogas is flared.

7.4 Project Emissions

Emissions resulting from all the activities/processes associated with the project are called project emissions. The project emissions must be accounted for each year in the monitoring period and include the following:

- The CO_2 emissions from electricity and fossil fuels used by the project facilities.
- The fugitive methane from the sludge treatment system.
- For CARB LCFS, flared biogas is not considered part of the project emissions because flaring is business-as-usual in the baseline. For voluntary programs considering baseline emissions from non-digester sources, flared biogas should be included in the project emissions.

7.5 Notable Differences from CA-GREET

CA-LCFS currently does not provide credit for using biosolids and digestate as a fertilizer. This methodology, however, offers the option of taking credit for using biosolids and digestate as a value-added product, including using it for fertilizer.

8.0 Food Waste

8.1 Definition

Food is the largest category of organic waste going into the landfill. In the U.S., 30% to 40% of food in the supply goes to waste.[12]

The below table from USEPA[13] gives a snapshot of the quantity of food waste generated and the various ways it is being treated from 1960-2019.

Table 8.1.1: 1960-2019 Data on Food in Municipal Solid Waste by Weight (in Thousands of U.S. tonnes)

Management Pathway	1960	1970	1980	1990	2000	2005	2010	2015	2017	2018	2019
Generation	12200	12800	13000	23860	30700	32930	35740	39730	40670	63130	66220
Recycling	0	0	0	0	0	0	0	0	0	0	0
Composted	-	-	-	-	680	690	970	2100	2570	2590	3300
Other Food Management	-	-	-	-	-	-	-	-	-	17710	13640
Combustion with Energy Recovery	-	50	260	4060	5820	5870	6150	7380	7470	7550	9650
Landfilled	12200	12750	12740	19800	24200	26370	28620	30250	30630	35280	39620

***Note that 2018 was the first year for which the USEPA used a new methodology, so the generation estimates increased due to the expanded scope of the new methodology.**

Food waste offers immense potential for biofuel generation. Food waste for this methodology is defined as unprocessed food discarded by grocery stores, wholesalers, and/or distributors.

Table 8.1.2: Definition of Wastes Eligible Under the Category of "Food Waste"

Waste Type	Description
Industrial Preprocessed Food Waste	Food materials that are considered of waste quality before entering an industrial process.
Food Scraps and Food-Soiled Papers	Food materials that are considered of waste quality at the point of delivery to small or large businesses or after being handled at those businesses, including grocery stores, restaurants, hotels, and wholesalers.

[12] https://www.fda.gov/food/consumers/food-loss-and-waste

[13] https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/food-material-specific-data#FoodTableandGraph

Household Food Waste	Food waste disposed of at home: food that was not ultimately consumed by humans that is discarded or recycled, such as plate waste (i.e., food that has been served but not eaten), spoiled food, or peels and rinds considered inedible.[14]
Farm Food Waste/Food Loss	Food materials that are considered of waste quality before leaving the farm for another destination. Unused products from the agricultural sector, such as unharvested crops.[15]

This methodology applies to all projects capturing, processing, and utilizing the biogas/biofuel generated from the digestion of food waste. Such projects present three-fold benefits: clean energy, methane reduction, and reducing food waste load in landfills.

The following types of project activities are eligible under this methodology:

- **Greenfield Project:** Plants/facilities with BCS.
- **Brownfield Plant:** Renovating/revamping existing plant to include BCS. Only projects are eligible that never had such a system in place in the facility's operational history.
- Facilities performing refurbishment to the existing BCS to ensure it continues to operate. A financial assessment must be performed to back the claim that carbon credit revenue is integral to this decision.

The following types of projects are ineligible under this methodology:

- Facilities performing refurbishment to the existing BCS for which existing incentives from governing bodies are sufficient for refurbishment.
- Changes to facility/plant operations resulting in overall increased efficiency of pre-existing BCS.

Additionality beyond what is listed in the General Conditions is found below.

1. **Regulatory Surplus:** All projects under the food waste category must demonstrate that they are neither fully nor partially required by any applicable laws and regulations in the region and state. To do so, the project design and outcomes must be cross-checked against the thresholds established by regulations applicable to the project type.
2. **Performance Standard Test:** Installing BCS as part of the project activity qualifies the project for Performance Test.

[14] https://www.epa.gov/sustainable-management-food/sustainable-management-food-basics
[15] https://www.epa.gov/sustainable-management-food/sustainable-management-food-basics

3. A financial viability assessment must be performed with and without carbon revenue. All incentives available for the project activity from local, state, and/or federal regulators must be considered while performing a financial viability assessment.
4. The type of biogas technology being utilized in the project must be assessed for its market penetration percentage within the national boundary of the project location. It must be demonstrated that the project activity is not yet commonly pursued.

8.2 Overall Boundary

The project boundary includes the physical and geographical site(s) of the project activity. System boundaries indicate the GHG SSR that must be included in a project assessment. Here, we adopt a gate-to-grave system boundary for biogas production. This means any GHG emissions associated with the collection, transportation, and processing (e.g., size reduction, digestion) of food waste to biogas, downstream transportation of biogas and end products, as well as end-use activities (if biogas is not upgraded for electricity and transportation fuel), must be included within the system boundaries of the biogas production (Figure 8.2.1). For end-use applications and system boundaries, please refer to Appendix A.

Figure 8.2.1: General System Boundary for Food Waste Digestion Baseline and Project Scenarios

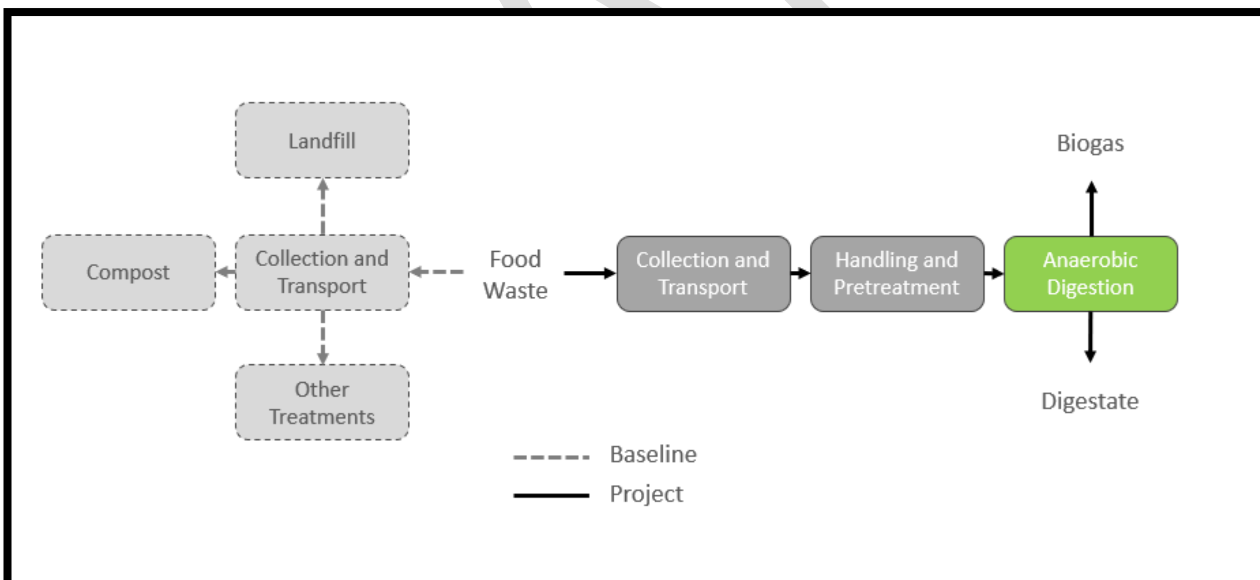


Table 8.2.3: GHG SSRs Included or Excluded from the Project Boundary

SSR	Emission Source	Gas	Baseline (B), Project (P)	Included/ Excluded	Justification
Feedstock Production	Fossil fuel consumption	CO_2, CH_4, N_2O	B	Excluded	Project activity will not impact emissions related to baseline activity.
Feedstock Collection	Fossil fuel consumption	CO_2, CH_4, N_2O	B	Excluded	Project activity will not impact emissions related to baseline activity.
Feedstock Transportation	Fossil fuel consumption	CO_2, CH_4, N_2O	B, P	Varies - See Justification	**Excluded -** Project activity will not impact emissions related to baseline activity if the waste is transported to the same site as in the baseline scenario. **Included –** The waste is transported to a different site than in the baseline.
Feedstock Treatment	Electricity consumption	CO_2, CH_4, N_2O	B, P	Included	**Baseline -** Electricity may be consumed from the grid or generated onsite.

					Project – Electricity consumed to process feedstock under project activity. This is in addition to electricity used in the baseline.
Feedstock Treatment	Fossil fuel consumption	CO_2, CH_4, N_2O	B, P	Included	Quantity of fossil fuels consumed to treat feedstock under project activity.
Feedstock Treatment	Emissions from mobile and stationary support equipment	CO_2	B, P	Included	If any additional vehicles or equipment is required by the project beyond the baseline, emissions from such sources shall be accounted for.
Feedstock Treatment	Direct emissions from anaerobic treatment of feedstock	CO_2	B, P	Excluded	The source is assumed to be biogenic, hence excluded.
		CH_4	B, P	Included	The primary source of GHG is affected by the project activity. Quantified

					using site and project-specific data for both Baseline and Project scenarios.
		N_2O		Excluded	
Product Related – Transportation of Final Product	Fossil fuel consumption	CO_2, CH_4, N_2O	P	Included	Quantity of fossil fuel used to transport the final product from the treatment site.

8.3 Baseline Emissions (Fugitive)

The baseline scenario for this project is when the food waste is not collected for digestion and biogas production. This will be a business-as-usual scenario when no changes to the existing system are made to convert waste to biogas.

Baseline GHG emissions are then those associated with the potential collection of waste for disposal (if any exists) and the decay of the waste over time (when landfilled, composted, or treated in other ways).

The time period for calculating the baseline emissions (BE) is one year of operation.

$BEi = BE_{CO2}, i + (GWP_{CH4} * BE_{CH4,i}) + (GWP_{N2O} *BE_{N2O,i})$

$BE_{CO2,i} = WM * EF_{CO2}$

$BEC_{H4,i} = WM * DOC * MW_{CH4}/MW_{C}$ * Model uncertainty factor

$BE_{N2O,i} = WM * EF_{N2O}$

8.4 Project Emissions

Emissions resulting from all the activities/processes associated with the project are called project emissions. The project emissions must be accounted for each year in the monitoring period and include the following:

- Direct emissions from activities like food waste collection, handling, and any treatment before anaerobic digestion.
- Indirect emissions from consumption of energy (e.g., electricity, natural gas) and materials like any chemicals used in the process.

The project emissions are then calculated as:

$PEi = PE_{CO2,\ i} + (GWP_{CH4} * PE_{CH4,i}) + (GWP_{N2O} * PE_{N2O,i})$

PEi: Project emissions for the reporting period, MT CO_2e/year.

8.5 Notable Differences from CA-GREET

CA-LCFS currently does not provide credit for using digestate as a fertilizer. This methodology, however, offers the option of taking credit for using digestate as a value-added product, including using it for fertilizer.

9.0 Other Organic Waste

9.1 Definition

This category includes all the other types of waste that do not fall under any of the described projects in this methodology.

Table 9.1.1 describes the waste types that are eligible to be included in the "Other Waste" project category.

Table 9.1.1 - Definition of Wastes Eligible Under the Category of "Other Organic Waste"

Waste Type	Description
Urban Landscaping Waste	Materials resulting from any public or private landscaping activities such as leaves, grass clippings, plants, pruning, shrubs, branches, and stumps.[16]
Agricultural/Farm/Crop Residue*	Materials left on cultivated land after the crop has been harvested (e.g., corn stover).
Industrial Biobased By-Products**	Distillers grain
Industrial Biobased Waste	Byproducts of industrial food processing***

*** This category does not include animal manure**
**** Distillers grain with prior applications/end markets is considered a co-product and would not be eligible as "other waste" here.**
*****This category does not include post-consumer food waste (e.g., grocery waste or household food waste). It also does not include wastewater sludge.**

This methodology applies to project activities that capture, process, and utilize biogas from projects. Projects that are applicable under this methodology/module are:

- Greenfield facilities.
- The addition or expansion of biogas capture at existing facilities.
- The refurbishment of BCS facilities that would have been decommissioned without the project.

The projects are not applicable under the following conditions:

- Efficiency improvement projects.
- Upgrades to existing facilities that are not at the risk of decommissioning.
- Changes in operational practices leading to improved biogas capture.

[16] https://ww2.arb.ca.gov/sites/default/files/classic/fuels/lcfs/cagreet/t1_biomethane_ow_instruction_manual_v04282023.pdf

9.2 Overall Boundary

The project boundary includes the physical and geographical site(s) of the project activity. System boundaries indicate the GHG SSR that must be included in a project assessment. Here, we adopt a gate-to-grave system boundary for biogas production. This means any GHG emissions associated with the collection, transportation, and processing (e.g., size reduction, digestion) of waste to biogas, downstream transportation of biogas and end products, as well as end-use activities (if biogas is not upgraded to electricity and transportation fuel), must be included within the system boundaries of the biogas production (Figure 9.2.1). For end-use applications and system boundaries, please refer to Appendix A.

Figure 9.2.1: General System Boundary for Other Organic Waste Baseline and Project Scenarios

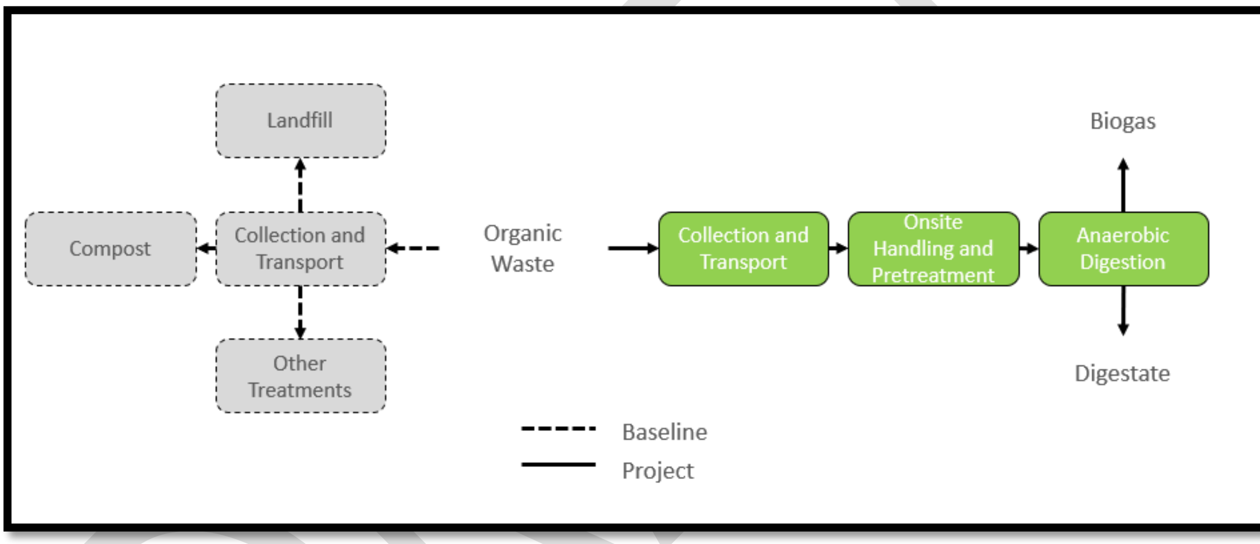


Table 9.2.1: GHG SSRs Included or Excluded from the Project Boundary

SSR	Gas	Baseline (B), Project (P)	Included/ Excluded	Justification
Electricity Consumption	CO_2, CH_4, N_2O	B, P	Included	If any electricity is used for the collection and treatment of waste for both baseline and project, electricity-related emissions must be considered.
Fuel Consumption	CO_2, CH_4, N_2O	B, P	Included	Emissions from burning fuel for collection and transport of waste for both baseline and project should be included.
Mobile and Stationary Support Equipment	CO_2	B, P	Included	Emissions from any additional vehicle or equipment used shall be accounted for.
Other Waste Treatment Process	CO_2 CH_4, N_2O	B, P	Included	If the treatment doesn't change, the emissions should stay the same between the baseline and the project.
Digestate Fate Emissions	CO_2	B, P	Excluded	Emissions from digestate degradation are considered biogenic.
	CH_4, N_2O	P	Excluded	Emissions related to digestate use, such as bedding, fertilizer, or anaerobic storage.
Enteric Fermentation	CH_4	B, P	Included	These emissions should be the same for both baseline and project.
Mechanical Systems Used to Collect and	CO_2	B, P	Included	The emissions from fuels used should be considered. If the

Transport Waste	CH_4, N_2O	B, P	Included	equipment stays the same between the baseline and project, their emissions can be excluded. Otherwise, emissions from any additional vehicle or equipment used shall be accounted for.

9.3 Baseline Emissions (Fugitive)

The baseline scenario for this project is when the waste is not collected for digestion and biogas production. This will be a business-as-usual scenario when no changes to the existing system are made to convert waste to biogas.

Baseline GHG emissions are then those associated with the potential collection of waste for disposal (if any exists) and the decay of the waste over time (when landfilled, composted, or treated in other ways).

The period for calculating the baseline emissions is one year of operation.

To calculate the baseline emissions, the mass and composition of the waste must be obtained. The method of obtaining the weight of the waste will depend on the type of the waste. Direct sorting and weighting will provide the most accurate estimate of the mass of the waste. However, in some cases, indirect calculations such as mass based on an average yield of corn stover from a field might be used if no direct measurements are available. In the absence of any available measured or calculated data, estimates and general emission factors can be used.

An example is the emissions associated with the degradation of waste, which can be estimated either 1) based on the composition of the waste and method of degradation (e.g., in the open fields, composted, or in a landfill), or 2) using average degradation emission factors if composition for a specific waste is not available.

Organic wastes that fall within urban landscaping waste or mixed organics recovered from MSW can use characterization (e.g., percentage of degradable organic carbon (DOC) from CA-GREET). If a waste cannot be categorized in any of the general waste categories, the following methodology can be used to estimate the DOC.[17]

$$DOC = F_{DOC} \text{ X } \frac{\%\, Volatile\ Solids}{100\%} \text{ X } \frac{\%\, Total\ Solids}{100\%} \text{ } (F_{DOC} \text{x } \%\text{ Vol Solids x Total Solids}/100\%)$$

Where:

[17] https://ww2.arb.ca.gov/sites/default/files/classic//fuels/lcfs/ca-greet/tier1-ow-im.pdf

F_{DOC} is the fraction of the volatile residue that is degradable organic carbon (weight fraction); use the default value of 0.6. % Total Solids = 100% - % Moisture Content.

A set of default DOCs for various types of waste is presented in Table 9.2.2,[18] where the data are adopted from the Greenhouse-Gas Emissions Estimation by RTI International. Project-specific values may be used for each facility if available.

Table 9.2.2: Degradable Organic Carbon Values for Landfills

Landfill Waste Type	DOC (Weight Fraction, Wet Basis)
All Bulk Waste, Unseparated	0.2028
Bulk MSW	0.30
Construction and Demolition Waste	0.08
Diapers	0.24
Food Waste	0.15
Food Processing Industry Waste	0.22
Garden Waste	0.20
Inert Waste	0.0
Other Industrial Solid Waste	0.20
Paper Waste	0.40
Pulp and Paper Industry Waste	0.20
Sewage Sludge	0.05
Textile Waste	0.24
Wood and/or Straw Waste, Wood Products	0.43

Baseline emissions are then calculated as follows:

$BEi = BE_{CO2,\,i} + (GWP_{CH4} * BE_{CH4,i}) + (GWP_{N2O} * BE_{N2O,i})$

$BE_{CO2,I} = WM * EF_{CO2}$

$BE_{CH4,I} = WM * DOC * MW_{CH4}/MW_{C}$ * Model uncertainty factor

$BE_{N2O,I} = WM * EF_{N2O}$

Where:

[18] https://www3.epa.gov/ttnchie1/efpac/ghg/GHG_Biogenic_Report_draft_Dec1410.pdf

$BE_{CO2,i}$: Baseline CO_2 emissions (MT CO_2)

$BE_{CH4,i}$: Baseline CH_4 emissions (MT CH_4)

$BE_{N2O,i}$: Baseline N_2O emissions (MT CH_4)

WM: Mass of the waste (MT)

MW: Molecular Weight. The molecular weight of CH_4 (MW_{CH4}) is 16 and the molecular weight of carbon (MW_C) is 12.

EF_{CO2}: The emission factor for CO_2 emission depending on the degradation method, e.g., composting.

EF_{N2O}: The emission factor for N_2O emission depending on the degradation method, e.g., composting.

GWP_{CH4}: Global warming potential of CH_4.

GWP_{N2O}: Global warming potential of N_2O.

Global warming potentials (GWPs) for CH_4 and N_2O are adopted from the latest IPCC report. GWPs for both baseline and project emissions, however, must be selected from the same IPCC report. IPCC AR6 reports[19] 29.8 for CH_4 of fossil origin, 27.2 for CH_4 of non-fossil origin, and 273 for N_2O GWPs.

9.4 Project Emissions

Project emissions include all direct and indirect emissions that occur as a part of the project during the project activities for each year in the monitoring period. These include:

- Direct emissions from activities.
- The indirect emissions from consumption of energy (e.g., electricity, natural gas) and materials.

The project emissions are then calculated as:

$PEi = PE_{CO2,\,i} + (GWP_{CH4} * PE_{CH4,i}) + (GWP_{N2O} * PE_{N2O,i})$

PEi: Project emissions for the reporting period, MT CO_2e/year.

9.5 Notable Differences from CA-GREET

CA-LCFS currently does not provide credit for using digestate as a fertilizer. This methodology, however, offers the option of taking credit for using digestate as a value-added product, including using it for fertilizer.

[19] https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Chapter07.pdf

Appendix A – End Uses

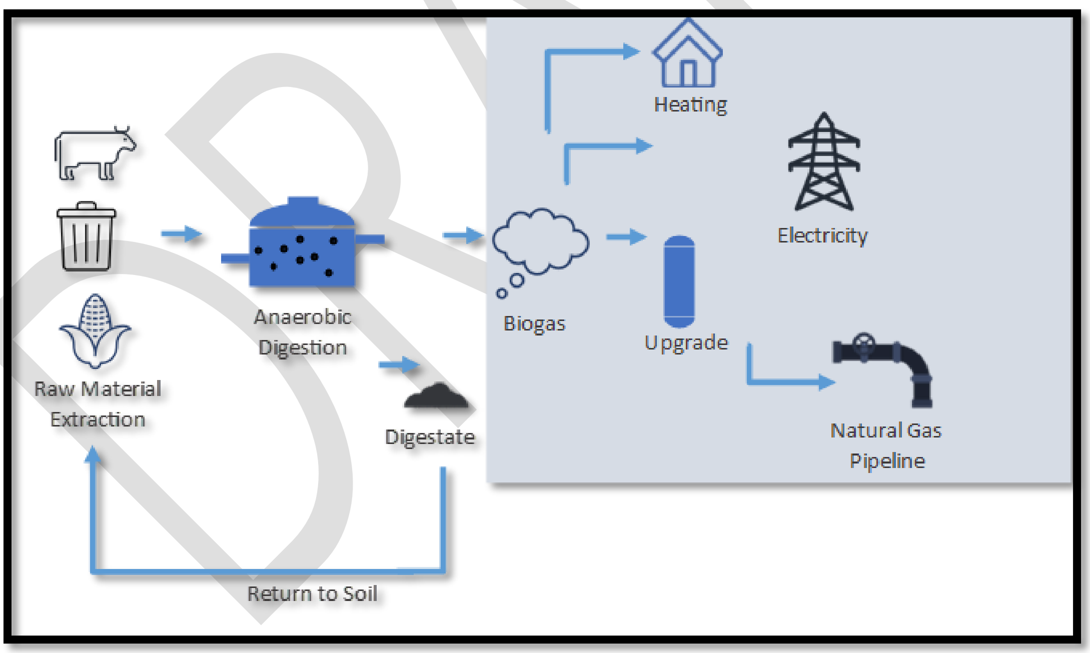
A.1 Measuring the Project CI for Various Biogas End Uses

This section describes the assumptions and methodology pertaining to calculating the CI for (upgraded) biogas to various end-uses. Once biogas is generated it can then be used for a variety of applications. Such end-use applications could include (but are not limited to):

1. Flaring
2. Converting to electricity
3. Upgrading to RNG and generating CNG for transportation fuel
4. Heating

The system boundary for the calculation of the portion of the emissions that occur between biogas production and an applicable end-use for that biogas starts from the produced biogas. The system boundary then continues with transportation (if necessary) and upgrading, injection, and transportation of biogas in the case of CNG and electricity. Combustion emissions at end use are also included.

Figure A.1.1: System Boundary



***The shadowed part demonstrates the system boundary of this section of the methodology.**

Each end-use application will have an end-use-specific functional unit to allow the final product produced through that pathway to be able to be compared with its counterparts that are being replaced. Table A.1.1 below serves as a general example.

Table A.1.1 – Functional Units to Report the CI Per Biogas End-Use

Electricity	kWh	Kg CO_2e/kWh
CNG	MJ	g CO_2e/MJ
Heating	MJ	g CO_2e/MJ

A.2 Flaring and Heating

We assume that for both flaring and home heating, no upgrading of the biogas has taken place. This means that biogas will be directly combusted to either provide energy for heating or to convert the methane content of the biogas to CO_2 before sending it to the atmosphere.

CI of the flaring and heating is then calculated as:

CI: (PEi / Biogi) $*10^6$ + Biog CH_4 * 44/16

PEi: Project emissions for the reporting period, MT CO_2e/year.

Biogi: Mass of biogas generated annually at the anaerobic digestor, MJ of biogas/year.

Biog CH_4: CH_4 content of one MJ of biogas (g CH_4/MJ of biogas).

44/16 represents the conversion of the CH_4 content to CO_2 once biogas is burned.

A.3 Electricity

For biobased electricity generation, biogas will be combusted so that the energy content of biogas can be converted to mechanical energy through various combustion technologies. Examples include internal combustion engines and gas turbines. The mechanical energy is then used in a turbo generator to generate electricity. This low-CI electricity should be used onsite.

Therefore, for electricity generation, the following emissions are included in the system boundary:

- Biogas transmission/transportation losses.
- Combustion and mechanical conversion losses.
- Direct emissions from combustion of biogas in boilers.

A.4 CNG for Transportation Fuel

For CNG production, biogas will be first upgraded to RNG and then in most cases transported/transmitted to a destination via pipelines before it is compressed and used as CNG. This system is referred to as "book-and-claim" accounting. The physical gas does not need to be used at the destination but instead, the environmental attributes are recorded (booked) and then traded to another party to capitalize on the benefits of low-carbon fuel (claim). Therefore, for CNG application the following emissions are included in the system boundary:

- Emissions resulting from upgrading of CNG to RNG.
- Biogas transmission/transportation losses.
- Emissions from energy use for compression of RNG to CNG.
- Direct emissions from combustion of CNG in vehicles.

Appendix B – Digestate Pathways

B.1 Digestate Guidance

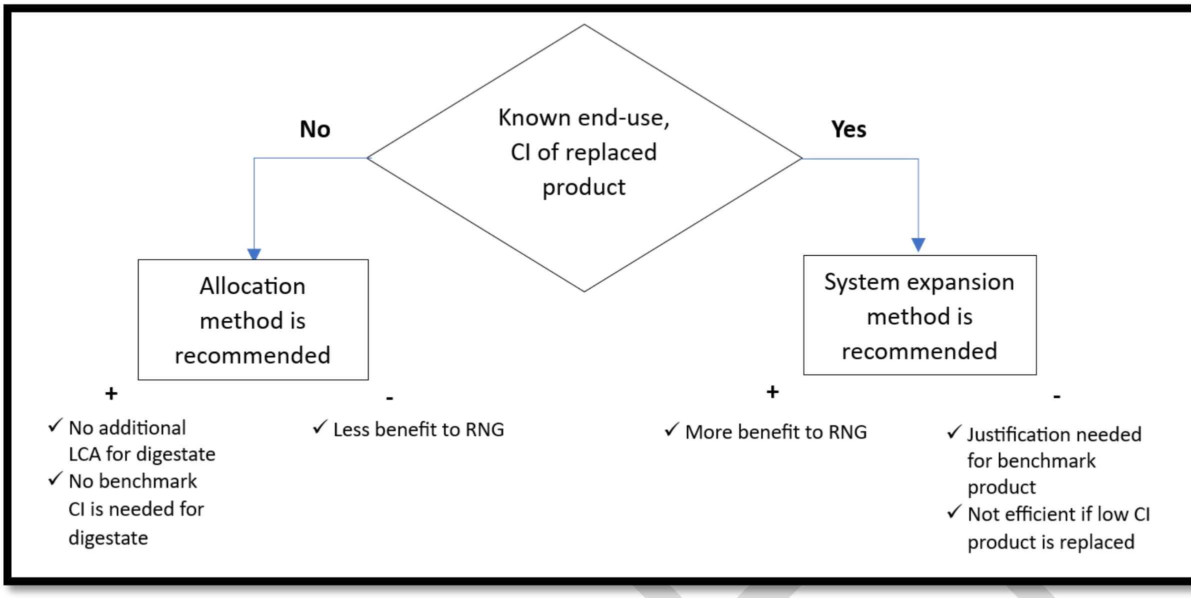
Digestate is the residual material left after anaerobic digestion, often consisting of materials that are not easily degraded and contain high levels of lignin. Whole digestate, like whole manure, is often a wet mixture and can be separated into liquid and solid components, both having multiple beneficial reuse opportunities. Most commonly, nutrient-rich digestate is used directly as fertilizer, but it can be further processed through aerobic composting. The solid portions can be dried and used as animal bedding.

All digestive substances remaining from the anaerobic digestion of animal manure, wastewater treatment, food waste, and other waste fall under this category.

A project that generates digestates can accrue credits from avoiding digestate from being treated as low-value material depending on the credit accounting method applied. Once digestate is considered of value, it is considered a co-product of the project rather than waste. The credit can then be assigned to a project depending on the selection of either allocation or system expansion accounting methods. Pursuing credits in the VCM for digestate use will require a system expansion approach as credits will be based on emissions avoided by offsetting a more carbon-intensive good.

Figure B.1.1 below provides recommended guidance for the approach selection. In addition, it shows the advantages and risks of each pathway.

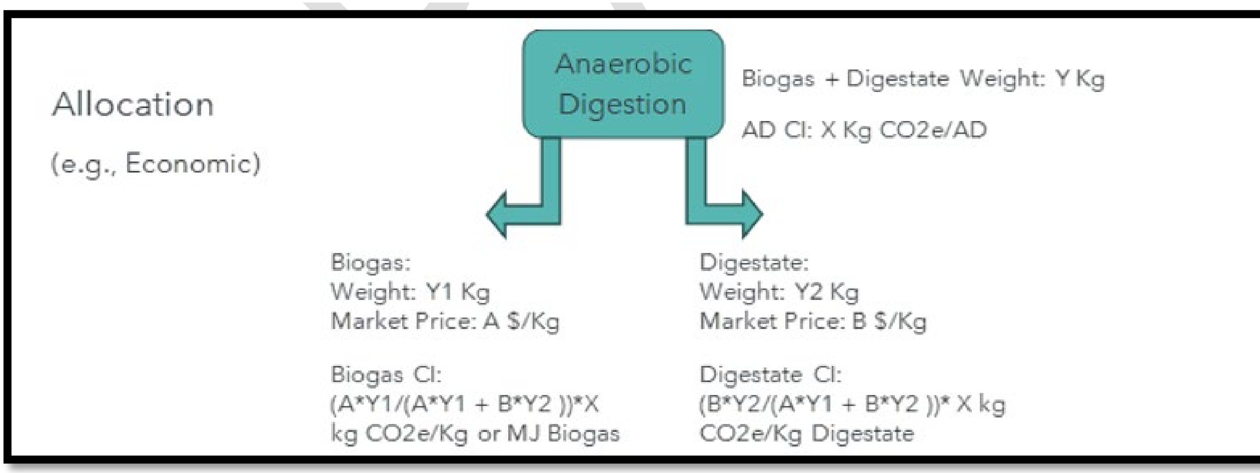
Figure B.1.1: Digestate Guidance



Allocation Accounting Method

In allocation accounting, the emissions are split between co-products. Co-product allocation is "partitioning the input or output flows of a process or a product system between the product system under study and one or more other product systems" [ISO 14044: 2006]. See Figure B.1.2 for a visual demonstration of the allocation accounting method in LCA.

Figure B.1.2: Visual Demonstration of Allocation Accounting Method in LCA



The following are the advantages of using allocation:

- Does not rely on the CI of the product it is displacing. For example, the digestate's CI will be estimated based on the anaerobic digestion process it is being obtained from and independent of the fertilizer it may be replacing.

- No additional LCA is needed for digestate as emissions could be applied solely on mass/energy content and proportion of the biogas versus digestate.

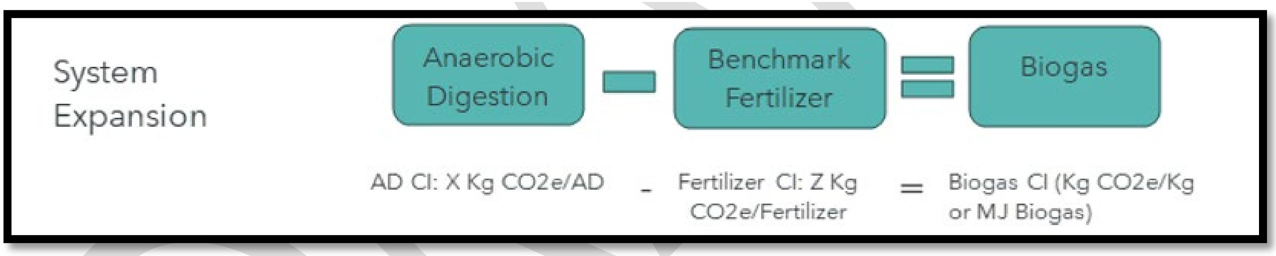
The following are the disadvantages of using allocation.

- Needs a decision on mass vs. economic allocation for digestate CI.
- Does not provide as much benefit to RNG, as system expansion might.
- The end-users (e.g., farmers) may not particularly be seeking a low-CI fertilizer/bedding as it might be irrelevant to their operation.

System Expansion

In system expansion, externalities (positive or negative) are considered and linked to the system, while they are not directly related to how a system operates or a product is made. Here, instead of partitioning the system's life-cycle emissions to the co-products, it is assumed that one of the co-products will replace its conventional counterpart in the market, and thus the avoided emission from such replacement is credited back to the main product system. Furthermore, the avoided emissions go back to biogas, which is considered the main product, and digestate is assumed to replace fertilizer in the market. See Figure B.1.3 for a visual demonstration of the allocation accounting method in LCA.

Figure B.1.3: Visual Demonstration of System Expansion Accounting Method in LCA



***The CI of benchmark fertilizer is subtracted from the overall anaerobic digestion process, leading to an improved CI for the biogas.**

The following are the advantages of using allocation:

- In theory, system expansion might provide a bigger CI benefit to RNG than allocation. The CI will depend on the benchmark fertilizer selected for replacement. If the benchmark fertilizer is a high CI, then replacing such fertilizer will generate a higher credit for the biogas system.
- This method covers the primary ask from the livestock owners (if possible) – People want to take credit for displacing fertilizer used on fields and they want to fold that into RNG market value. In regulatory areas, they are not allowed to take these benefits.

The following are the disadvantages of using allocation.

- It could be cumbersome to calculate fertilizer for each region/market. Selecting a benchmark fertilizer may be a subjective matter. Specific guidelines need to be set for selecting eligible fertilizers with respect to their applicability for a specific farming management practice, crop, and soil type.
- Effort may not result in a positive impact compared to allocation if a relatively low-CI fertilizer is being replaced.

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