DAIRY METHANE ACCOUNTING

A guide for disaggregating dairy methane emissions from existing corporate greenhouse gas inventories

Environmental Defense Fund
Pure Strategies Inc.


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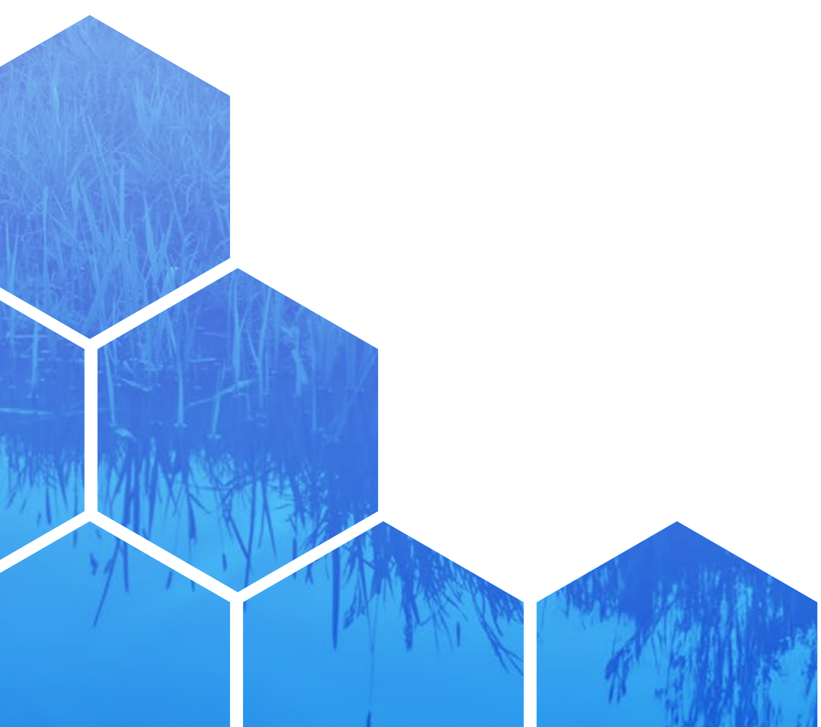

Environmental Defense Fund

One of the world's leading international nonprofit organizations, Environmental Defense Fund (EDF), creates transformational solutions to the most serious environmental problems. To do so, EDF links science, economics, law, and innovative private-sector partnerships. With more than 3 million members and offices in the United States, China, Mexico, Indonesia, and the European Union, EDF's scientists, economists, attorneys, and policy experts are working in 28 countries to turn our solutions into action.

Dairy Methane Action Alliance

The Dairy Methane Action Alliance (DMAA) is a global initiative to accelerate action and transparency on methane across the dairy sector. By joining this groundbreaking initiative, signatory companies commit to account for and publicly disclose methane emissions within their dairy supply chains and to publish and implement a comprehensive methane action plan. Environmental Defense Fund and the sustainability nonprofit Ceres will help to ensure companies are making progress against key milestones.

At the time of printing this guide in the fall of 2024, DMAA signatories include:
Bel Group, Clover Sonoma, Danone, General Mills, Kraft Heinz, Lactalis USA, Nestlé, and Starbucks.

Pure Strategies Inc.

Pure Strategies is a sustainability consulting firm that empowers brands, retailers, and NGOs to realize meaningful environmental and social improvement. Founded in 1998, Pure Strategies helps companies on their sustainability journey with a focus on goal setting, effective management strategies, and redesigning products and supply chains that deliver value to the business and society.

Acknowledgments

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Bel Group, Clover Sonoma, Danone, General Mills, International Dairy Federation (IDF), Kraft Heinz, Lactalis USA, Nestlé, and Starbucks.

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The complete report is available online at https://business.edf.org/dairy-methane-accounting.

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LAURENCE RYCKEN
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FOREWORD

Environmental Defense Fund (EDF) has long demonstrated a strong commitment to driving meaningful climate action through collaboration. Recognizing that complex challenges like dairy methane emissions require coordinated efforts, EDF has actively engaged with a diverse set of stakeholders to ensure that their guidelines reflect the realities and needs of all involved. Their willingness to work across public and private sectors exemplifies the power of public-private partnerships in achieving impactful, sustainable solutions. By bringing together governments, industry, and civil society, EDF fosters a holistic approach where all voices are heard, and each plays a vital role in the collective effort to mitigate methane emissions. It is through this collaborative spirit that we can ensure robust and practical solutions that will make a tangible difference in reducing dairy's global environmental footprint.

The dairy sector plays a vital and holistic role in addressing climate change, contributing to both global environmental sustainability and food security. Pursuing ambitious climate action in the dairy sector promises a triple win, benefiting farmers' livelihoods, food security, and the climate. While the dairy sector has been proactively taking steps to address climate change, methane mitigation presents the industry with a tremendous opportunity to play a leading role in lowering near-term warming, helping to enhance food security worldwide. Although much of the public debate focuses on ruminants, it is important to note that milk from the main dairy animals —cattle, buffalo, goats, and sheep — stands for less than 15% of the anthropogenic methane released, which accounts for 60% of the total methane emissions. On the other hand, methane emissions from the agricultural/dairy sector originate from short-cycled natural biological processes.

A well-planned approach is crucial to ensure that strategies are adopted to maximize the reduction of greenhouse gases (GHGs) in the dairy sector. Holistic, science-based methodologies like life cycle assessment (LCA) and carbon footprinting are widely acknowledged as key tools for evaluating emissions throughout a product's entire life cycle, from production to consumption. International Dairy Federation (IDF) has played a pivotal role in developing guidelines and methodologies that support these efforts. Moreover, IDF has reviewed the guidance from EDF and has provided technical support and alignment with the Bulletin of the IDF N°520/2022: The IDF global Carbon Footprint standard for the dairy sector.

Effective climate action depends on supportive political and regulatory frameworks that incentivize sustainable practices, drive the adoption of innovative technologies, and fund critical research. Equally important is fostering collaboration among all stakeholders, a goal actively pursued by the Environmental Defense Fund. We are grateful for their continued engagement and partnership in this vital effort.

Laurence Rycken
Director General
International Dairy Federation

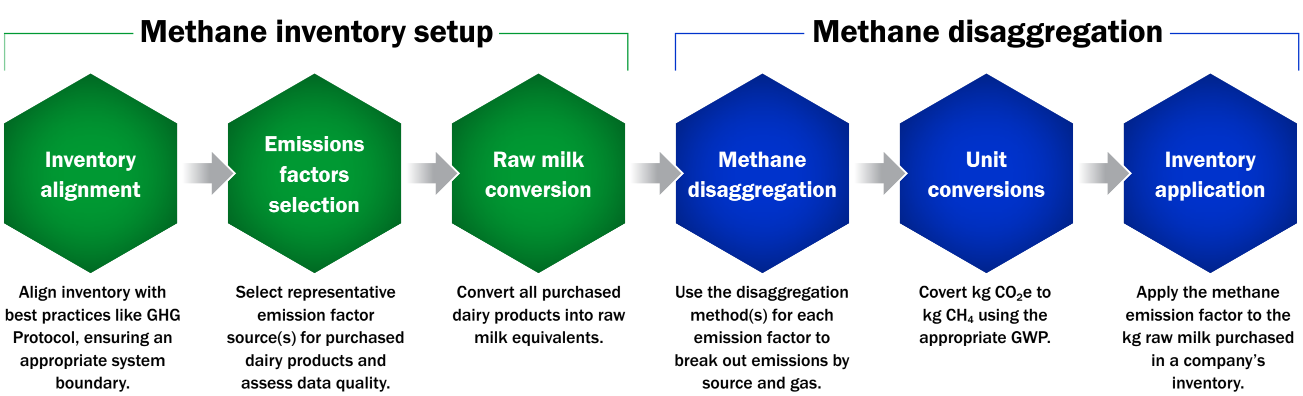
EXECUTIVE SUMMARY

Methane emissions from agriculture, in particular from dairy cattle, need to be a major focus for emissions-reduction activities globally, given methane's high potency and short-lived nature in the atmosphere. Dairy sector companies leading on climate are increasingly aware of the critical role they must play in driving methane reductions, and as a result, are prioritizing methane mitigation by measuring and disclosing their methane emissions, setting emissions reduction targets, assessing their impacts, and engaging on farm to drive reductions. The Dairy Methane Action Alliance (DMAA) and Environmental Defense Fund (EDF) are developing guidance to help companies eager to take a leadership position on dairy methane work through every stage of this process.

To act on methane, dairy companies must first understand their total dairy-related methane emissions. However, until this point, existing technical guidance and accounting frameworks have lacked the direction to disaggregate dairy-related emissions by greenhouse gas (GHG) and process in the value chain (e.g., enteric fermentation, manure management, feed). DMAA has published this first-ever publicly available technical guidance for dairy companies to disaggregate methane emissions using commonly referenced emission data sources to address this gap.

This guide takes a step-by-step approach to developing a methane inventory. It first walks a company through the steps needed to ensure their corporate GHG inventory is set up to allow for methane disaggregation and then details the methodology for disaggregating methane.

FIGURE 1
Methane GHG inventory development process



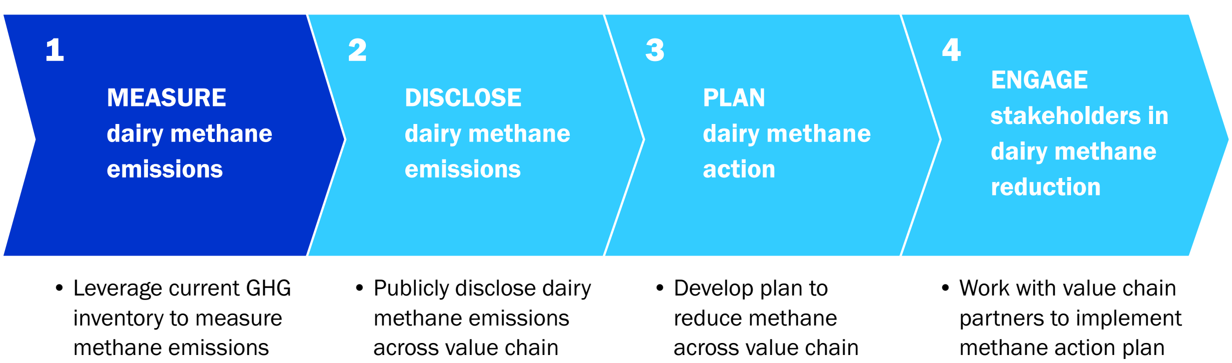
Since methane disaggregation depends on the emission factor (EF) source used, this guide walks through the disaggregation for commonly referenced EF sources:

- **Custom factors:** EFs from a peer-reviewed LCA commissioned by a company to calculate the emissions of their direct milk supply.
- **Modeling tools:** EFs derived from online calculation tools or software that are designed to take data inputs and calculate emissions based on model parameters.
- **Literature values:** EFs from peer-reviewed studies or LCA databases.
- **Unknown sources:** EFs from sources lacking data transparency.

Choosing appropriate EFs is essential to accurately disaggregate methane emissions from a GHG inventory. This guide provides a "Good-Better-Best" ranking system based on each data type's ability to disaggregate EFs by gas and source (e.g., enteric fermentation, manure management, feed) as well as customize data by geography, technology, time period, farm size, production system, and other factors that contribute to dairy emissions. This guide does not recommend companies use one source over another. Instead, it provides commentary on how to select the best EF source for developing a methane-specific inventory.

Upon working through this guidance document, a company will have the knowledge and tools needed to develop a methane-specific inventory from their corporate GHG inventory. From there, companies can then determine their methane hotspots for public disclosure to help prioritize action in driving meaningful dairy methane emissions reductions. This methane accounting guide is the first document released as part of the Dairy Methane Action Alliance (DMAA) initiative to drive action on dairy methane.

FIGURE 2
Dairy Methane Action Alliance (DMAA) initiative trajectory



INTRODUCTION

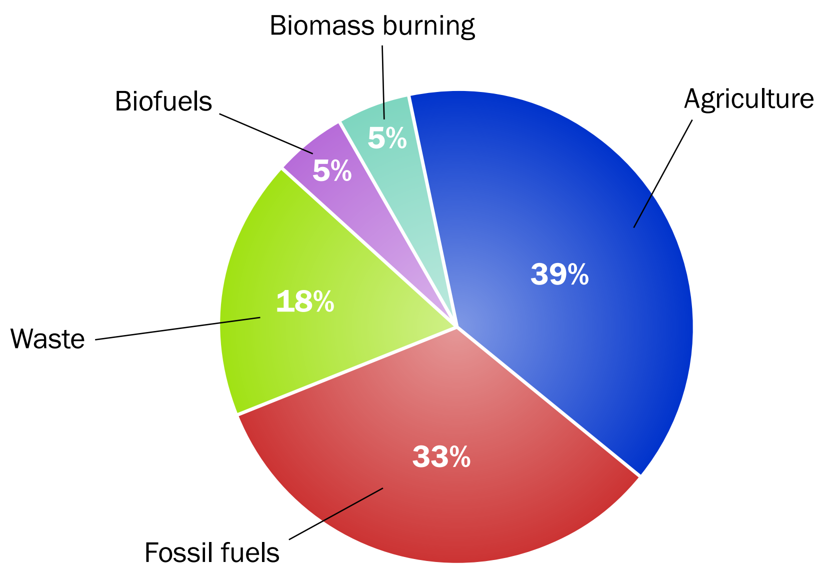
INTRODUCTION

Background

Globally, food systems contribute approximately one-third of all anthropogenic greenhouse gas (GHG) emissions.[1] Livestock agriculture contributes a significant portion of those emissions, accounting for nearly 15% of total global anthropogenic emissions.[2] Livestock agriculture, primarily cattle production, is also the single largest source of agricultural methane (CH_4), responsible for around 32% of anthropogenic methane emissions.[3]

Specifically, methane from enteric fermentation and to a lesser extent, manure management, together account for well over half of livestock emissions, with dairy cattle representing approximately 10% of global methane emissions.[4]

FIGURE 3
Sources of anthropogenic methane emissions[5]



In the short term, methane has a particularly high potency, with the ability to trap more than 80 times as much heat as carbon dioxide (CO_2) in the first 20 years after its release into the atmosphere. Despite its outsized impact on warming, methane only remains in the atmosphere for a relatively short number of years — compared with hundreds of years for CO_2.

Because of methane's short-lived nature and high potency compared to CO_2, reducing it can help immediately slow the rate of warming in the next few decades while we work to curb CO_2 emissions to meet the Paris Agreement's 1.5C target. According to the United Nations Environment Programme's Global Methane Assessment, methane emissions should be reduced by at least 40-45% by 2030.[6]

Given that methane from enteric fermentation and manure management make up a significant portion of overall emissions in dairy supply chains, the dairy sector has a significant opportunity to reduce its methane impact. Near-term action on methane is one of the most effective ways for companies to progress on their climate goals, reduce the systemic risk of climate change, and increase resilience in their operations and supply chains.

Visibility to methane emissions can help dairy sector companies identify and target the most impactful GHG reduction opportunities. Disaggregating methane emissions from other GHG emissions is critical to support this aim, however, many accounting methodologies are not yet set up to do this.

Purpose of the guide

This guide was developed to help companies with existing corporate GHG inventories disaggregate dairy methane emissions, building upon existing standards, such as:

- International Dairy Federation (IDF) Bulletin N°520/2022: The IDF global Carbon Footprint (CF) standard for the dairy sector
- European Dairy Association (EDA) Product Environmental Footprint Category Rules (PEFCR) for Dairy Products
- Greenhouse Gas (GHG) Protocol Standards
- Innovation Center for U.S. Dairy Scope 3 GHG Inventory Guidance For U.S. Dairy Cooperatives and Processors

While these documents together provide a basis for calculating emissions from dairy ingredients/products and developing a corporate GHG inventory, they do not provide a methodology to explicitly disaggregate methane emissions.

This guide aims to address this gap by assisting companies with significant dairy sourcing across their supply chain in determining the methane component of dairy GHG emissions. Given the outsized contribution of methane in dairy supply chains (approximately 60%), prioritizing methane is critical to achieving corporate climate targets. This guide is meant to enable methane measuring, reporting, and mitigation planning. In particular, this guide will:

- Provide a methodology for companies operating in the dairy sector (e.g., processors/manufacturers, producers/farmers, etc.) to measure their methane emissions across the dairy value chain, with particular emphasis on farm-level dairy methane.

- Allow companies to develop their own dairy methane inventories, which they can leverage to reveal dairy methane hotspots, disclose dairy methane emissions, and identify opportunity areas for dairy methane mitigation.

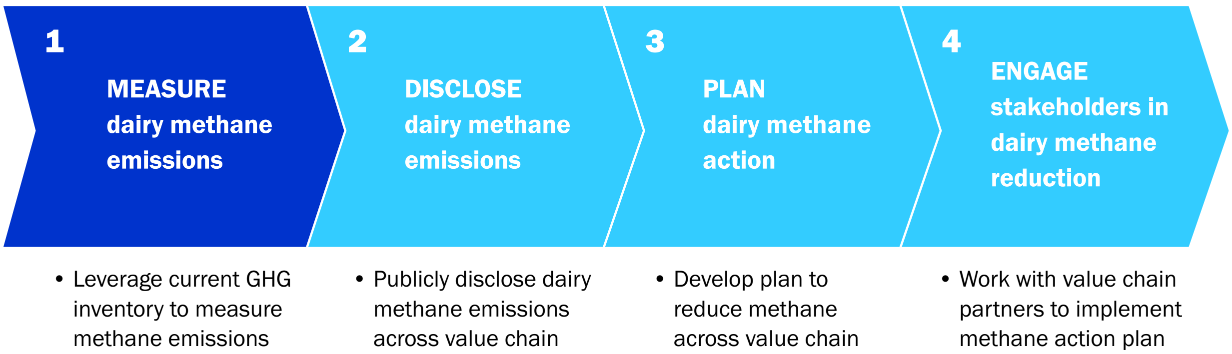
- Propose a framework for both categorizing and rating different dairy emission factor (EF) sources based on their ability to disaggregate GHGs by gas and activity (e.g., enteric fermentation, manure management, feed) and customize data inputs based on different production systems and data quality criteria.

If companies using this guide are still working to develop their corporate GHG inventories or are refining them in line with the GHG Protocol Land Sector and Removals Guidance and the Science Based Targets initiative (SBTi) Forests, Land and Agriculture (FLAG) Guidance, please refer to the sources listed above and throughout this document to support this work.

This methane accounting guide is the first guidance document to be released as part of the Dairy Methane Action Alliance (DMAA) initiative.

FIGURE 2

Dairy Methane Action Alliance (DMAA) initiative trajectory



Sources of dairy methane emissions

The following section describes the largest sources of cradle-to-farm gate methane—enteric fermentation and manure management. This section covers the most material methane emissions sources since this work focuses on addressing the main methane mitigation opportunities.

FIGURE 4

Sources of emissions from global dairy cattle systems, 2015[7]

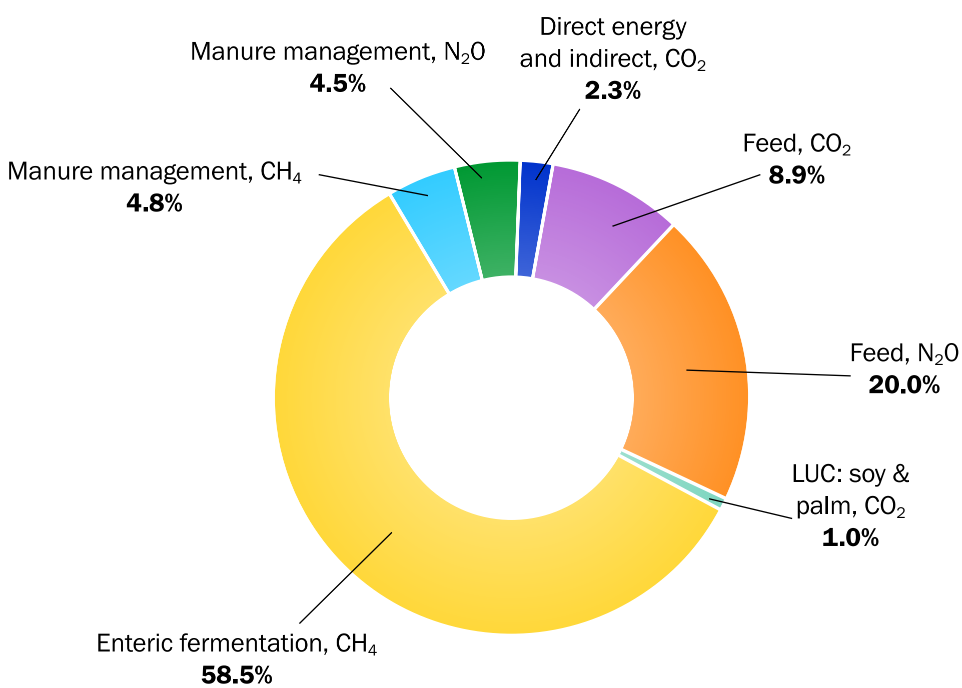
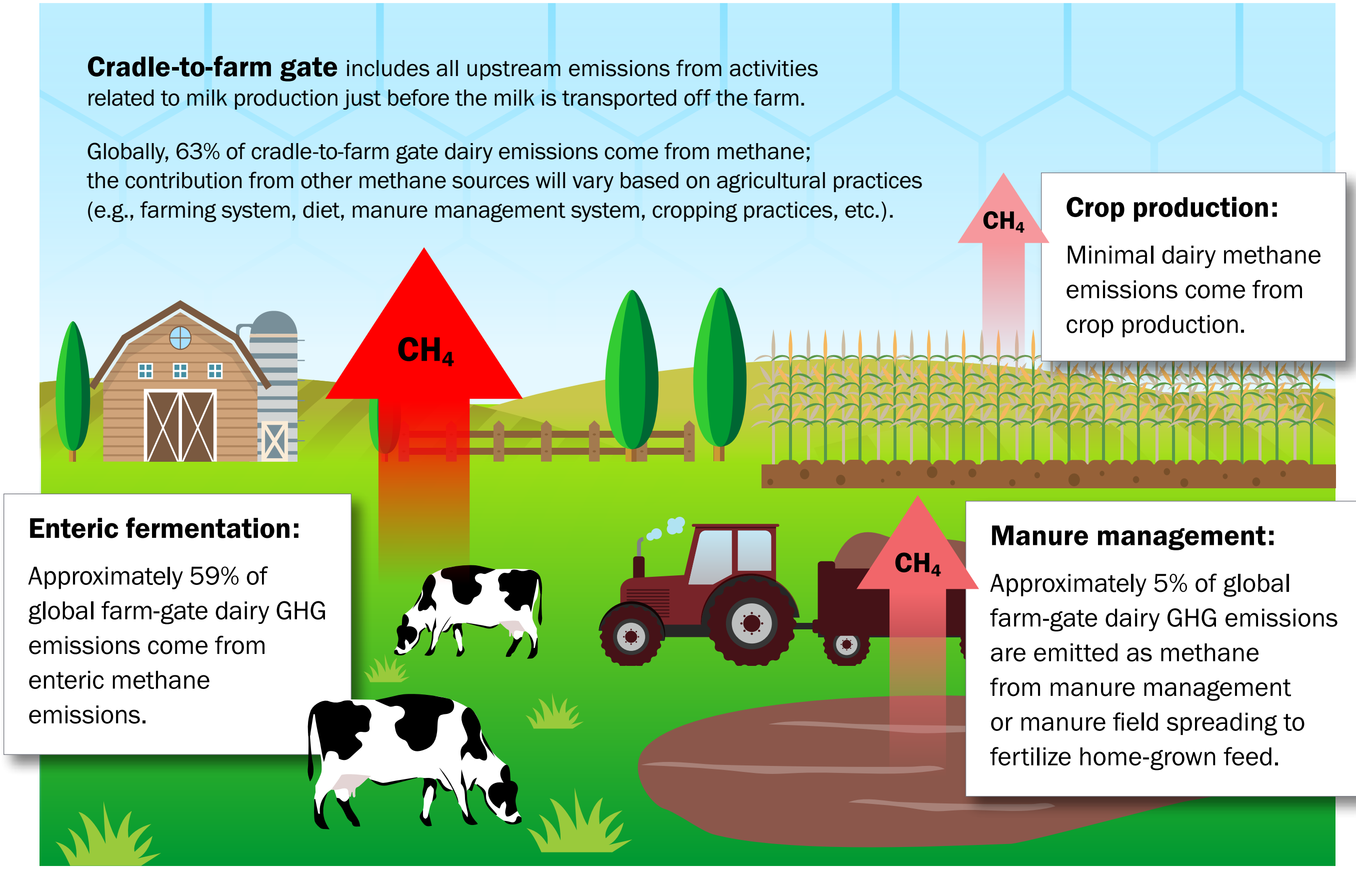


FIGURE 5

Global cradle-to-farm gate dairy methane hotspots[7]



Source: Bizzarri, G. (2019). Climate change and the global dairy cattle sector: The role of the dairy sector in alow-carbon future. https://www.fao.org/3/CA2929EN/ca2929en.pdf

Enteric fermentation

Like all ruminant animals, dairy cows, heifers, calves, and bulls produce methane as part of their natural digestion processes. This methane is produced as a by-product of enteric fermentation in the rumen, where microbial fermentation breaks down the dietary fiber that is otherwise difficult to digest. It is also the largest source of GHG emissions in dairy farming, accounting for up to 59% of all cradle-to-farm gate GHG emissions.

Manure management

Manure management is the second largest source of methane in the dairy supply chain. While nitrous oxide (N_2O), another highly potent GHG, is not discussed in detail as part of this guide, manure management is also responsible for significant N_2O emissions. There are multiple methods of managing manure on dairy farms, including liquid storage, composting, daily spread on fields, solids separation, and anaerobic digestion. When solids are separated from the manure liquid they can be used for multiple purposes, including as bedding in the barn. Methane emissions from manure storage vary and depend on the temperature, amount of liquid/moisture, length of storage time, cover, and geometry of the manure storage facility. Some farmers utilize technology and aggressive management practices to reduce methane formation and/or release from their storage facility, including adding a cover to capture escaping gases or separating liquid from the manure before storage.

Generally, anaerobic, oxygen-poor manure management conditions, such as manure lagoons, produce more methane than aerobic, oxygen-rich conditions, such as manure composting. This is why methane from manure management is typically lower for pasture-based farms than for confined dairy operations.[8] Methane from manure management accounts for an average of 5% of on-farm dairy emissions globally but has been noted to account for up to 19% in more intensive operations.[9]

Feed production

Manure used to fertilize home-grown dairy feed, rice used in compound dairy feed, and agricultural residue burning all result in limited amounts of methane from feed production. These sources of methane are negligible as compared to methane from enteric fermentation and manure management and will not be addressed in detail throughout this document.[10, 11]

Food loss and waste

The Food and Agricultural Organization (FAO) defines food loss as the decrease in the quantity or quality of food resulting from decisions and actions by upstream food suppliers in the chain, and food waste as the same, except by downstream retailers, food services, and consumers.[12] Approximately one-third of all food intended for human consumption is lost and wasted every year across the entire supply chain—14% from food loss and 17% from food waste.[13]

Upstream food loss occurs at the farm level for a company processing dairy products. Losses in processing and manufacturing occur within a company's own operations. Downstream food waste can occur during transportation and distribution, at retail, and finally, at the consumer level.

Food loss and waste occurring at different levels of the supply chain will have varying environmental impacts. Consumers account for the highest portion of food waste, with 43% of food waste occurring at the final stage of the value chain.[14] When food is wasted further downstream, the environmental impacts are compounded. In addition to the end-of-life disposal emissions, resources, such as time, energy, and financial resources required to get the product to this stage, are also wasted. Thus, addressing food waste has a two-fold benefit in reducing methane emissions: less milk production and less organic waste.

See Appendix 1: Food loss emissions for additional detail and context.

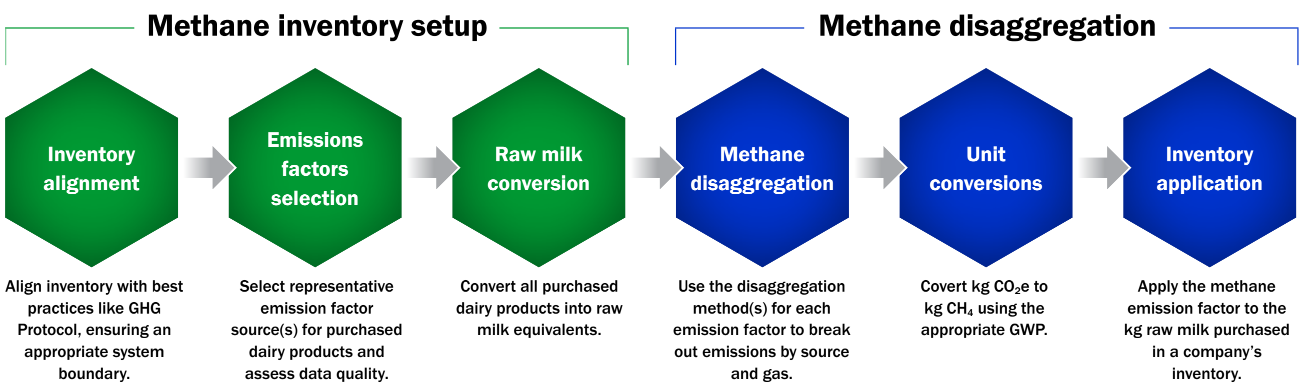
METHANE INVENTORY SETUP

METHANE INVENTORY SETUP

Before a company can calculate its dairy methane footprint, various steps and decisions are needed to prepare its overall inventory for methane disaggregation. Figure 1 summarizes the process for developing a methane GHG inventory from an existing corporate GHG inventory.

FIGURE 1

Methane GHG inventory development process

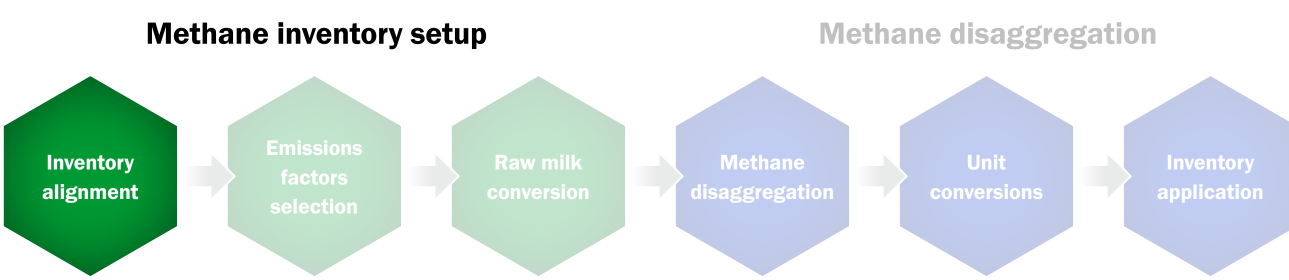


A company's inventory may already be set up for methane disaggregation. However, it is recommended that companies review the following sections to ensure their inventory aligns with the GHG Protocol, uses appropriate raw milk emission factors (EFs), and converts all dairy products to raw milk equivalents before moving on to methane disaggregation. The following section of this guide will walk through the inventory setup process. While this section is not exhaustive in including all the steps needed to set up a GHG inventory, it provides the key highlights for this work.

Inventory alignment

FIGURE 1.1

Methane GHG inventory development process: Inventory alignment



Before companies are able to disaggregate methane emissions, it is important that their corporate inventories are aligned with industry best practices, such as the GHG Protocol Corporate Standard and Corporate Value Chain (Scope 3) Standard. It is also important that the appropriate boundaries are selected for their Scope 1, 2, and 3 emissions based on their level of financial and/or operational control.

GHG inventory approach

This document uses a corporate GHG inventory accounting approach rather than a life cycle assessment (LCA) or product carbon footprint (PCF) accounting approach to account for dairy methane, so the guidance may differ from some of the standards and guidance documents referenced.

Key differences between LCA/PCF and inventory accounting approaches stem from the boundary and timeframe used in the analysis. LCAs evaluate and report different environmental impacts (e.g., water use, land use, freshwater eutrophication, etc.) across the full life cycle and lifespan of a product or service, including raw material extraction, manufacturing or processing, transportation, use, and end-of-life management. A PCF is a subtype of LCA that only looks at carbon emissions rather than a suite of environmental impacts.

In contrast, a GHG inventory catalogs all emissions from an organization's operations and value chain over a set period (often one year). GHG inventories are used as tools to establish baselines, track GHG emissions, and measure reductions over time for an organization. This guide utilizes an inventory accounting approach since companies are working to mitigate dairy methane emissions across their value chains rather than a specific product's life cycle. While the system boundary for these accounting approaches differ, they use the same methodology for calculating emissions at the farm level. Additional information on developing a GHG inventory for a dairy sector company can be found in the IDF CF standard and Innovation Center for U.S. Dairy Scope 3 GHG Inventory Guidance For U.S. Dairy Cooperatives and Processors.

Results from PCFs can be leveraged to develop a corporate GHG inventory. However, companies must adjust the study's boundary and/or timeframe to align with their level of corporate control.

System boundary

A system boundary is the subset of the overall system that is studied in an LCA or PCF. When working between PCFs and GHG inventories, it is important that the system boundary of the emissions from the PCF aligns with the boundary of the scope and category defined in the GHG inventory, based on what part of the value chain the emissions occurred and the company's level of control.

Figure 6 summarizes the emission scope(s) associated with each node of the dairy value chain and each value chain actor. While the level of financial and operational control varies based on the companies or entities involved, Figure 6 is meant to illustrate typical value chain responsibilities.

FIGURE 6

Dairy methane emissions scope by life cycle stage and value chain actor

Value chain actor	Purchased inputs (e.g., feed, fertilizer)	Milk production (including feed production, enteric, manure management)	Transportation/ distribution (across value chain nodes)	Processing	Retailing	Use (e.g., home refrigeration)	End-of life
Farmer/ producer	Scope 3	Scope 1	Scope 3	Typically Scope 3 Scope 1,2 if farmer processes milk	Scope 3	Scope 3	Scope 3
Cooperative	Scope 3	Scope 1,2 if own/operate farms Scope 3 if do not own/operate farms	Scope 1,2 if own/control means of distribution Scope 3 if do not own/control means of distribution	Scope 1,2 if own/operate processing facility Scope 3 if do not own/ operate processing facility	Scope 3	Scope 3	Scope 3
Processor/ manufacturer	Scope 3	Scope 1,2 if own/operate farms Scope 3 if do not own/operate farms	Scope 1,2 if own/control means of distribution Scope 3 if do not own/control means of distribution	Scope 1 and 2	Scope 3	Scope 3	Scope 3
Logistics provider/ distributor	N/A	N/A	Scope 1 and 2	N/A	N/A	N/A	N/A
Retailer	Scope 3	Scope 1,2 if own/operate farms Scope 3 if do not own/operate farms	Scope 1,2 if own/control means of distribution Scope 3 if do not own/control means of distribution	Scope 1,2 if own/operate processing facility Scope 3 if do not own/operate processing facility	Scope 1 and 2	Scope 3	Scope 3
Consumer	Scope 3	Scope 3	Scope 3	Scope 3	Scope 3	Scope 1 and 2	Scope 3

Cradle-to-farm gate boundary

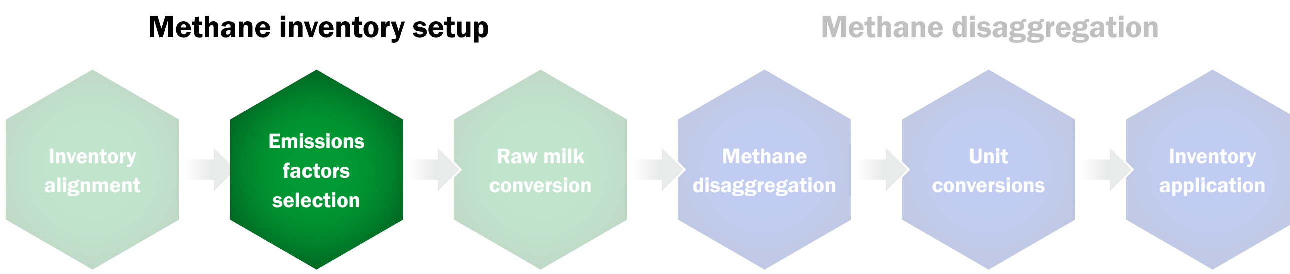
The boundary of "cradle-to-farm gate" is a common system boundary used to account for the emissions from purchased milk. This boundary includes all upstream emissions related to animal feed production and milk production activities up to just before the milk is transported off the farm.

For use in their GHG inventory (as part of their Scope 3 Category 1 emissions from Purchased Goods and Services), a processor might separate the cradle-to-farm gate milk emissions from a PCF that accounts for the entire carbon footprint of a kilogram (kg) of raw milk. Emissions from other stages of the milk product life cycle, such as refrigeration in retail or disposal of the product and packaging by the consumer, would be analyzed separately to ensure assumptions related to the company's activities and operational control are appropriately modeled.

The cradle-to-farm gate boundary is also used because it allows users to measure progress on farms and compare farms, farming systems, co-operatives, regions, and countries. Note that there are other system boundaries used in LCAs and PCFs, such as cradle-to-factory gate and cradle-to-grave. However, this guide primarily uses a cradle-to-farm gate approach since this is geared toward accounting for agricultural dairy methane.

Emission factors selection

FIGURE 1.2
Methane GHG inventory development process: Emission factors selection



After companies have aligned their inventories with the GHG Protocol using the appropriate boundaries and timeframes, they must then select appropriate EFs for purchased dairy products that represent their supply chain.

Emission factors and global warming potentials

Companies must consider the EFs used to represent the carbon impact of dairy-related activities across the value chain to account for dairy methane emissions from an existing GHG inventory. EFs represent the amount of GHGs emitted from a specific source or activity. EFs are often aggregated into carbon dioxide equivalents (CO_2e), combining all relevant gases based on their global warming potentials (GWPs). GWP is a measure of the relative influence of a unit (e.g., 1 kg) of a GHG on global temperature within a given time horizon, commonly over a 100-year or 20-year period.[15] Expressing non-CO_2 GHGs as CO_2e involves weighing gases by their GWP, compared to CO_2.[16] This guide uses 100-year GWPs (GWP100) with CO_2 as the reference gas (CO_2 having a 100-year GWP of 1), in line with ISO 14067, GHG Protocol, and other guidance, per industry best practice.[17,18,19]

BOX 1

Methane global warming potentials (GWPs)

Because GWPs are based on their relative potency and lifetime in the atmosphere, methane has varying climate impacts when assessed over different time horizons. For example, over a 100-year timeframe, methane is nearly 30 times as impactful as CO_2, whereas over a 20-year timeframe, methane is about 80 times as impactful. Understanding methane's impact in the short term (20 years) can help companies understand the magnitude of methane mitigation needed to reduce warming.

Another metric, GWP*, proposes a way to account for the fluctuations of flow gases in the atmosphere. GWP* does not account for warming from existing atmospheric concentrations, only from emissions causing more or less warming over a time period. The goal for managing methane as a short-term climate pollutant should be to reduce emissions to slow the rate of warming by mid-century rather than pursuing a goal of no net warming. For this reason, GWP* is not an appropriate metric for setting corporate climate mitigation targets. Multi-stakeholder initiatives across the world, including the Global Methane Pledge and IPCC, recognize methane reduction as a key step to limit warming to well below 2°C.

This document provides guidance for disaggregating methane emissions using 100-year GWPs, as many prominent industry stakeholder groups, such as the Intergovernmental Panel on Climate Change (IPCC), Greenhouse Gas Protocol (GHGP), and Science-Based Targets initiative (SBTi), use this timeframe in their research, guidance, and standards. Many EF sources referenced in this document also only use 100-year GWPs (e.g., CFT, GLEAM, etc.). Other EFs provide the option to calculate methane emissions using 20-year GWPs (e.g., LCA databases). If dairy companies are interested in calculating their 20-year methane impact, they will need to disaggregate emissions by GHG using the appropriate GWP100 factor and multiply the weight of methane in the process they are assessing by the 20-year methane GWP.

In their effort to convert all GHGs to CO_2e, each of these GWP conversions falls short in adequately demonstrating both the short- and long-term impact of each GHG on global climate change. By developing a methane-specific inventory measured in the raw value of kilograms of methane—a consistent value across all GWPs—companies can use this objective measure to mitigate their methane impacts. Ultimately, EDF recommends that companies set targets specific to each non-CO_2 gas (i.e., CH_4 and N_2O) rather than grouping them all together.

For additional information on methane GWPs, refer to EDF's Ambitious Climate Mitigation Pathways for U.S. Agriculture and Forestry: Vision for 2030 Report.

The Methane disaggregation for raw milk emission factors section of this guide provides guidance on how to disaggregate methane from common EF sources used to calculate dairy-related GHG emissions.

Choosing appropriate EFs is key to accurately disaggregating methane emissions from a GHG inventory. This guide provides a framework for categorizing different EF types based on their ability to customize dairy production parameters. The EF categories explored include custom EFs, modeling tools, literature values, unknown data sources, and stacking of different EF types across distinct value chain areas. These EF categories are then rated using a “Good-Better-Best” tiering, based on the ability to disaggregate EFs by gas and source (e.g., enteric fermentation, manure management, feed) as well as customize data by geography, technology, time period, farm size, production system, and other factors that contribute to dairy emissions. Some EF sources automatically break out emissions by gas and/or value chain process (e.g., feed production, milk production, transport), while others require estimates from multiple sources. Figure 8 outlines each EF type by its Good-Better-Best rating. It is important to note that this guide does not prescribe specific data sources for use in a GHG inventory, rather it aims to illustrate how to disaggregate methane emissions from common data types and provide a framework for continuous improvement.

While this guide does not require the use of certain data sources, if GHG emissions from milk or dairy products are an inventory hotspot, it is not recommended to use spend-based EFs, or economic input-output models to track GHG emissions. This is because when using spend-based data, it can be difficult to trace the source of emissions (e.g., enteric vs. manure management), track progress over time, and develop a concrete mitigation plan.

BOX 2

Primary versus secondary data

For the purposes of this guide, **primary** data is defined as original data collected from the source of emissions (e.g., data collected from a farm). **Secondary** data is defined as data collected from sources other than direct measurement of the emissions from defined process(es) (e.g., data collected from a non-farm supplier) and used when primary data is not available or practical to obtain.

BOX 3

IPCC livestock and manure management model

The Intergovernmental Panel on Climate Change (IPCC) is a body of the United Nations whose purpose is to advance scientific knowledge about climate change caused by human activities. Their 2006 Guidelines For GHG Inventories (updated in 2019) provide calculation methodologies for countries to estimate and report their GHG emissions by sector. Relevant to the dairy sector, Volume 4, Chapter 10 of the guidelines covers Emissions from Livestock and Manure Management. This chapter provides the methodologies and frameworks for estimating methane emissions from the dairy sector and is a foundational approach used in many EF sources discussed below.

The IPCC model uses a tiered approach, where each tier represents a certain level of methodological complexity and primary data requirements. Ball et al. describe each IPCC methodological tier:[20]

- *"Tier 1 models incorporate basic data, commonly rely on IPCC-recommended default values at the country level and are not specific to individual sites. These models are typically employed at a national or regional scale, providing a broad overview of the potential climate impacts.*
- *Tier 2 models operate at an intermediate level of complexity and incorporate some site-level data. Tier 2 models are often used at the national or sub-national level, offering a more detailed assessment of the potential climate impacts within specific sectors, such as agriculture or energy.*
- *Tier 3 models, the most complex, demand extensive data and are best suited for providing site-specific estimates. Tier 3 models are typically applied at a local level and offer a highly detailed assessment of management change outcomes within specific ecosystems, such as a farm or river basin."*

To calculate methane emissions, detailed data on animal population, feed intake, feed composition, manure excretion, and manure management practices are required as inputs into IPCC equations, with each tier relying more on primary data inputs. Many of the EF sources discussed below integrate IPCC guidelines into their calculation methodologies, most commonly using the Tier 2 or Tier 3 approach.

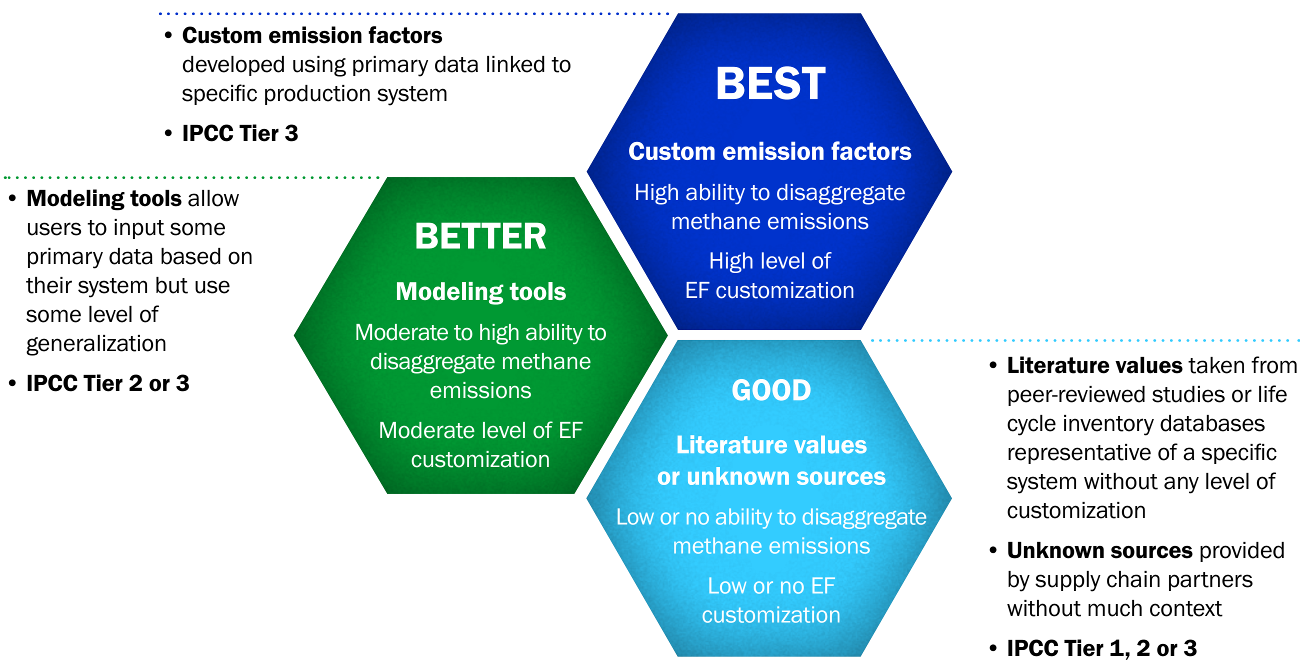
Emission factor data quality

High-quality and transparent data are necessary to understand the magnitude of dairy methane hotspots within a company's value chain and provides companies with the basis to act on and reduce their dairy methane. Having visibility into the sources of methane (i.e., methane-emitting processes) and quantity of methane emitted, allows companies to identify the key areas for methane mitigation. The more accurate and detailed the data that is gathered, the more easily companies can identify targeted methane mitigation strategies.

The following criteria should be considered when evaluating data:

- Transparency of assumptions
- Understanding whether it is a primary or secondary source
- Adequate documentation for continuous improvement over time
- Temporal representativeness
- Geographical or regional representativeness
- Technological representativeness
- Technical characteristics of the production system
- Understanding of rounding assumptions
- Completeness
- Appropriate management of variation and uncertainty

FIGURE 7
Emission factor types by good-better-best rating



For example, understanding the type of manure management system that is in place on a dairy farm and the climate where that farm is located can help determine what potential manure management alternatives might be available to the farmer.

Finally, while data quality is important for accurate accounting and intervention analyses, companies must balance seeking high-quality data with efficiency and practicality.

For additional content on data quality requirements, refer to section 5.1 of the IDF CF standard.

FIGURE 8

Emission factor data summary

EF source	EF category	GHG disaggregation by gas	GHG disaggregation by source	IPCC tier	GWP timeframe	GWP value source[a]	System boundary	Results normalization
CUSTOM FACTORS								
Custom factor[b]	Custom	✓	✓	3	100, 20	IPCC AR6: 27	Cradle-to-farm gate	FPCM
MODELING TOOLS								
CAP'2ER	Modeling tool	✓	✓	1, 2, 3[c]	100	IPCC AR6: 27.2	Cradle-to-farm gate	FPCM
COMET-Farm	Modeling tool	✓	✓	1, 2, 3[c]	100	IPCC AR4: 25	Cradle-to-farm gate without upstream impacts from feed/fertilizer	Emissions by herd group
Cool Farm Tool	Modeling tool	✓	✓	2	100	IPCC AR6: 27.9	Cradle-to-farm gate	FPCM
FARM ES	Modeling tool	✓	✓	2	100	IPCC AR4: 25	Cradle-to-farm gate	FPCM
GLEAM	Modeling tool	✓	✓	2	100	IPCC AR6: 27	Cradle-to-processing gate	FPCM, raw milk
Holos	Modeling tool	✓	✓	2	100	Reports in kg CH_4	Cradle-to-farm gate	Whole farm emissions
LITERATURE VALUES								
LCA database, activity data	Literature value	✓	Varies	Varies (Tier 1 or Tier 2)	Varies (commonly 100, 20)	Varies	Varies	Varies
LCA study (academic journal article)[d]	Literature value	Varies	Varies	Varies (Tier 1 or Tier 2)	Varies	Varies	Varies	Varies
LCA database, spend-based data	Literature value	✓	✓	Varies (Tier 1 or Tier 2)	Varies	Varies	Varies	Dollar
OTHER								
Unknown source	Unknown source	Varies	Varies	Varies (Tier 1 or Tier 2)	Varies	Varies	Varies	Varies

[a] *EF sources using the same IPCC report may still use different GWP due to the use of different draft versions before the final report was published. GWPs used in modeling tools are subject to change when the models are updated.*

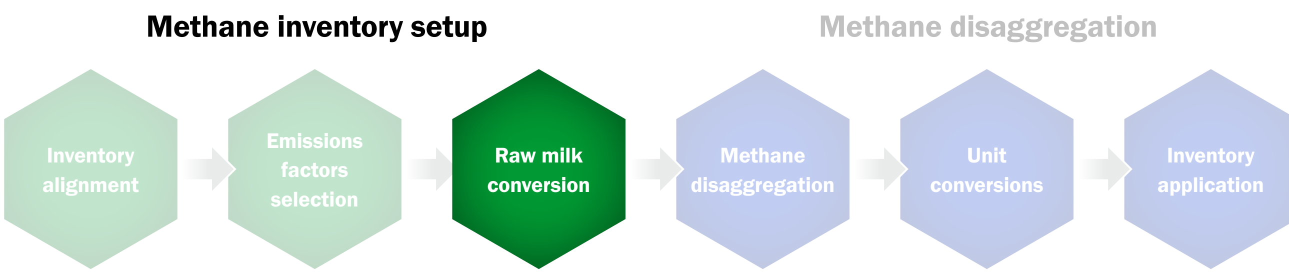
[b] *Custom factors will vary based on how the study is set up. The information provided in this table represents the ideal study setup for disaggregating methane.*

[c] *Modeling tools can use Tiers 1, 2, and 3 for different aspects of the model. For example, CAP'2ER uses a Tier 3 methodology to calculate methane from enteric fermentation, a Tier 2 methodology to calculate emissions from manure management, and a Tier 1 methodology to calculate N_2O emissions from the soil.*

[d] *Since the ability to disaggregate methane across literature studies varies, it is typically not the best EF source for methane disaggregation. Most commonly, literature studies will break out enteric methane, but not methane from manure management and report results using GWP100 with the most recent GWP characterization factor.*

Raw milk conversion

FIGURE 1.3
Methane GHG inventory development process: Raw milk conversion



Converting from raw milk to fat- and protein-corrected milk (FPCM)

A functional unit (FU) "expresses the function of a studied product or service in quantitative terms and serves as a basis of calculations. It also serves as a unit for comparison."[21] This guide provides guidance for breaking out dairy methane using EFs with the FU of 1 kilogram (kg) of fat- and protein-corrected milk (FPCM) produced from cradle-to-farm gate. FPCM represents a mass of milk standardized to a set content of fat (4.0%) and protein (3.3%) and is used to compare yields, resource use, or efficiencies across production systems. The FPCM quantity may be higher or lower than the raw milk quantity, depending on the fat and protein content of the raw milk.

The FU of FPCM was selected based on best practices outlined in section 4.3.2 of the IDF CF standard. When disaggregating methane emissions from an existing inventory, dairy producers and processors should use 1 kg of FPCM from cradle-to-farm gate as their dairy FU. For dairy producers, this FU represents the boundary of activities that occur within their operations and includes Scope 1 emissions and Scope 3 Category 1 emissions from purchased goods and services (e.g., purchased feed, fertilizer inputs, etc.) needed to run their dairy operations. For dairy processors, this FU represents their Scope 3, Category 1 dairy emissions from purchased goods and services. Emissions from transportation to the processor and dairy processing would then be captured elsewhere in their GHG inventory, as the processors' Scope 1 and 2 emissions. Additional information on GHG emission scopes can be found in Figure 6, Dairy methane emissions by scope and value chain actor and the GHG Protocol Corporate Accounting and Reporting Standard.

Since this guide uses an FU of 1 kg FPCM milk, GHG inventories must first convert all milk- and dairy-containing products produced or purchased into standard FPCM milk amounts to separate methane emissions from other GHG emissions.

The formula for calculating FPCM for cradle-to-farm gate EFs with known fat and true protein content is represented by Equation 1.

EQUATION 1

Formula for calculating the FU (kg FPCM) for cradle-to-farm gate EFs

$$\text{FPCM (kg)} = \text{milk production (kg)} \times [0.1226 \times \text{fat\%} + 0.0776 \times \text{true protein\%} + 0.2534]$$

For additional information on using FPCM as an FU, refer to section 4.3.1 of the IDF CF standard.

Converting from processed dairy products to FPCM

Dry matter (DM) or milk solids content is defined as the non-water component of a dairy product and includes carbohydrates, protein, fat, and minerals.[22] The European Dairy Association (EDA) Product Environmental Footprint Category Rules (PEFCR) recommends that dairy processors use the mass of dry matter (DM) to analyze the carbon footprints of different processed dairy products. This is because the manufacturing of dairy products typically begins with the single common input of raw milk and results in different outputs with distinct nutritional compositions and, thus, DM content. For companies that purchase processed dairy products, DM content can be used to understand the raw milk equivalents and, therefore, the emissions associated with processed dairy products.

Dairy manufacturers and brands must consider the carbon footprint of finished goods when they purchase processed dairy products, such as milk powder or cheese, as an ingredient in their processing or as a co-manufactured product. If supplier-specific EFs cannot be obtained for these purchased dairy products, DM content can be used to estimate the appropriate EFs. This can be done by starting with a supplier EF for milk, in kg CO_2e/kg FPCM, or if that is not available, using the best available industry EF for milk, also in kg CO_2e/kg FPCM, and attributing the milk emissions to the DM content of the purchased dairy product. Emissions are calculated by multiplying the dairy EF by the ratio of dairy product DM to the DM of FPCM (12.15%).[21] See Equation 2 below for additional information and an example calculation.

For reference, the DM content of many dairy products can be found in Appendix 1 of this guide, as provided by the EDA PEFCR. Note that different regions and/or sources have distinct definitions of FPCM DM content. For example, the EDA considers the average DM for FPCM whole milk to be 12.3%, whereas the IDF uses 12.15%. It is important to reflect these assumptions in calculations. Further, since food losses from processing raw milk into other dairy products can contribute a significant amount of GHG emissions, companies should also account for these potential losses in their calculations.

Companies that want to provide dairy product EFs to their customers can develop these using the cradle-to-farm gate EF of the milk inputs used to make the finished good, the DM content of the finished good itself, and the energy inputs required to process the milk into the finished good. Companies can then use their own production data or industry data (as in Appendix 1) to determine the amount of FPCM needed to produce the dairy product and calculate the EF for the dairy product using Equation 2 below.

Deriving the EF of a purchased dairy product with a known DM is illustrated in Equation 2, and the example below.

EQUATION 2

Formula for deriving the cradle-to-processing gate emission factor of purchased dairy products based on dry matter (DM) (plus losses at manufacturing)

$$EF\ DP_i = \left[\frac{\left[\left[\frac{DM\ DP_i}{DM\ FPCM_x} \right] * EF\ FPCM_x \right] + [(E_i) * (EF\ E_i)]}{(100\% - L_i)} \right]$$

Where:

EF DP$_i$: cradle-to-processing gate EF (kg CO_2e/kg DP$_i$) for dairy product i

DM DP$_i$: dry matter content of dairy product i (expressed as % dry matter or as weight by mass of dry matter/weight by mass of product i). Appendix 2 provides a table with proposed default values by dairy product

DM FPCM$_x$: dry matter content of FPCM for specific dairy production system x (expressed as % dry matter or as weight by mass of dry matter/weight by mass of FPCM). IDF provides a standard value of 12.15% dry matter for FPCM[21]

EF FPCM$_x$: cradle-to-farm gate EF (kg CO_2e/kg FPCM) for specific dairy production system x

L$_i$: % loss at factory for product i

E$_i$: amount of energy required to manufacture 1 kg of dairy product i

EF E$_i$: energy EF (kg CO_2e/ unit) of energy used in E$_i$

Example:

In this example, a dairy brand wants to calculate the cradle-to-processing gate carbon footprint of mozzarella cheese purchased from a co-manufacturer in the United States.
The following parameters are known, and assumptions were made:

- DM of mozzarella cheese is assumed to be 42.6%, per default values provided in Appendix 2
- DM of FPCM is assumed to be 12.15%, per default value shown in table above
- The cradle-to-farm gate EF is assumed to be 1.13 kg CO_2e/kg FPCM, per FAO EF from the GLEAM model for North America
- Energy required to produce 1 kg of mozzarella is assumed to be 0.5 kWh of electricity, as provided by the supplier
- The energy EF is 0.389 kg CO_2e/kWh of electricity using the average United States electricity grid, per eGRID 2021
- Loss at factory is assumed to be 4%, as provided by the supplier
- All other solid outputs (e.g., whey) were used for human consumption, so absorbed their portion of the burden

The cradle-to-farm gate EF, plus losses at the factory gate for 1 kg of purchased mozzarella using Equation 2:

$$\text{EF mozzarella} = \left[\frac{\left[\left[\frac{42.6\%\ \text{DM mozzarella}}{12.15\%\ \text{DM FPCM}} \right] \times 1.13\ \text{kg}\ CO_2\text{e/kg FPCM} \right] + [(0.5\ \text{kWh}) \times (0.389\ \text{kg}\ CO_2\text{e/kWh})]}{(100\% - 4\%\ \text{loss})} \right] =$$

4.33 kg CO_2e/kg mozzarella purchased

Looking at the first half of the equation, it would take approximately 3.51 kg of FPCM to produce 1 kg of mozzarella, per the specifications outlined above. Multiplying the mass of FPCM by the EF of the FPCM yields the EF of the milk needed to produce the mozzarella. The second half of the equation adds emissions associated with processing as well as any losses or waste that take place during the manufacturing process. Note that processing emissions were included in Equation 2 above for completeness; however, they should not be included when disaggregating methane emissions from cradle-to-farm gate, as processing is not a material source of methane emissions from the dairy producer. While many producers may not have visibility into factory-level losses, engaging with suppliers to understand losses from these purchased dairy ingredients can provide a more accurate and holistic look at dairy emissions.

When dairy products are manufactured in-house, all waste or food loss that is part of the manufacturing process is already captured in the company's GHG inventory by calculating the carbon emissions of all raw milk purchased, rather than the emissions of the finished goods produced. When purchasing processed dairy products from an external entity, companies must collect data on or make assumptions about the losses associated with the manufacturing of the product. Table 45 of the EDA PEFCR provides default values for loss rates from farm to retail when primary data is not available.

Companies should ideally engage with their suppliers to obtain specific values used in Equation 2 to model a system most representative of their supply chain. However, if supply information is unavailable, industry average values obtained from literature or industry groups can be used as proxies.

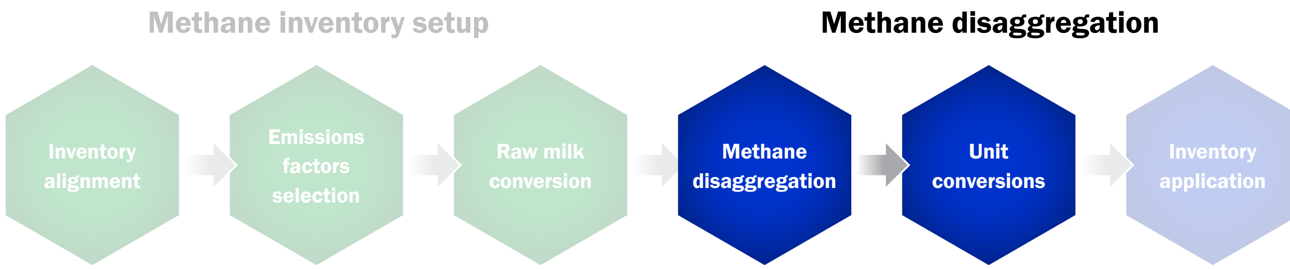
Appendix 2 provides default values for dry matter content of different dairy products as presented in Annex 5 of the EDA PEFCR. Refer to section 5.8.3 of the EDA PEFCR for additional information on how to allocate different dairy products for a PCF.

METHANE DISAGGREGATION FOR RAW MILK EMISSION FACTORS

METHANE DISAGGREGATION FOR RAW MILK EMISSION FACTORS

FIGURE 1.4

Methane GHG inventory development process: Methane disaggregation and unit conversion



Once a company has set up its inventory in alignment with the GHG Protocol, selected emission factors (EFs), and determined total raw milk equivalents in purchased dairy products, it must then disaggregate methane emissions from the raw milk EFs used in its inventory and convert the EF units into kg of CH_4. Disaggregation methods will vary based on the source used for each EF. Some EF sources directly disaggregate and report emissions by source (e.g., enteric fermentation, manure management, feed) and gas, while others may disaggregate emissions by one or the other. Some EF sources lack the information needed to disaggregate emissions, and thus, methane emissions must be estimated using a proxy.

This guide provides a general rating system of EF types based on how customizable an EF is and its ability to disaggregate methane. The following sections outline common EF sources under three categories: custom emission factors, modeling tools, and literature values. Methodology is also provided for breaking out methane when the EF provides no disaggregation or the EF is derived from an unknown source. Further, this guide will walk through the process of integrating methane EFs into an inventory and provide guidance on how to do this when multiple EF sources are used.

Each of the below sections will walk through an overview of the EF source and detailed methods for disaggregating methane from each source. Since EFs are typically reported in kg CO_2e, once disaggregated, the methane portion of the EF must be converted from kg CO_2e to kg CH_4. Box 4 walks through the steps for this conversion and provides guidance on which GWPs to use. Once emissions are disaggregated into kg CH_4/kg FPCM, they can be applied to a company's methane inventory.

BOX 4

Converting between kg CO_2e and kg CH_4 using GWP100

GWPs are reported in the IPCC assessment reports and can change slightly year over year based on advancements in the underlying science. Since the IPCC Second Assessment Report (SAR), GWP100 reported for methane has varied from 21 to 34. It is recommended that companies use the most up-to-date GWP100 value from AR6 when possible: 27 for non-fossil (biogenic) methane.[23]

EF sources may use varying GWPs for methane when determining CO_2e depending on the date they were published. To convert CO_2e emissions or an EF to methane, it is important to use the same GWP listed in the EF source. This guide lists the current (as of 2024) GWP used for each EF source. However, it is important to note that these can change, particularly when version updates of modeling tools are released.

If a company would like to then convert their methane emissions back into CO_2e, it is recommended that the non-fossil GWP100 from AR6 (GWP100 CH_4 = 27) is used, as that is based on the latest science. However, if a company has used a different GWP for its baseline methane emissions, it is crucial that the same GWP is used across all inventories to ensure consistency.

Sample calculations for this conversion are shown below:

$$CH_4 = (EF_{CH_4} \times FPCM) / GWP_{CH_4}$$

Where:

CH_4: methane emissions (kg CH_4)
EF_{CH_4}: methane intensity (kg CO_2e/kg FPCM)
FPCM: total fat and protein corrected milk (kg FPCM)
GWP_{CH_4}: GWP used by EF source

Example:

A company is using a milk EF of 1.25 kg CO_2e/kg FPCM. Using the methane disaggregation methods outlined in the sections below of this guide, it is determined that 0.80 kg CO_2e/kg FPCM is attributed to methane. The EF source states that the AR4 GWP100 of 25 for methane is used. The company wants to determine its methane emissions for the 50,000 kg FPCM that it purchases.

EF_{CH_4}: 0.80 kg CO_2e/kg FPCM

FPCM: 50,000 kg

GWP_{CH_4}: 25

$$CH_4 = (0.80 \text{ kg } CO_2e/\text{kg FPCM} \times 50{,}000 \text{ kg FPCM}) / 25 = 1{,}600 \text{ kg } CH_4$$

To report this back into kg CO_2e, it is recommended to use the non-fossil GWP100 from AR6 (GWP100CH_4 = 27):

$$CH_4\ CO_2e = 1{,}600 \text{ kg } CH_4 \times 27 = 43{,}200 \text{ kg } CO_2e$$

Custom factors (best)

Custom EFs provide a farm-specific method for modeling an EF using primary data. They represent the best approach for EF development and allow for the full disaggregation of methane. A peer-reviewed life cycle assessment (LCA) commissioned by a company to calculate the environmental impact of raw milk from their suppliers is an example of a custom EF. While this is considered the best approach given the high level of customization and ability to disaggregate methane, this is not a common practice among companies as it is a relatively data- and resource-process.

Overview of emission factor source

A custom factor can be developed internally or externally by a third party. The IDF CF standard walks through a standardized methodology for developing an EF using an LCA approach. Custom factors can take many different forms and range in their level of data quality. They can rely entirely on primary data collection for all aspects of the study, but can also leverage models, such as IPCC, to estimate methane emissions if direct on-farm measurements are not feasible.

Data requirements

Data requirements for custom factors will depend on the methodology used. There are a number of methods for directly measuring on-farm methane from dairy farms, with ranging levels of complexity and accuracy. Bekele et al. provides an overview of various methods, providing commentary on their advantages and disadvantages.[24] For enteric fermentation, spot sampling methods, such as GreenFeed, may be used on a subset of cows during milking or feeding to provide estimates of methane emissions rates scaled over a period of time. For manure management, enclosure chambers or micrometeorological techniques may be used.[25]

Where field experiments are not possible, modeling based on IPCC methodology can be used. When selecting the IPCC model for custom factors, the Tier 3 approach should be used as it includes the most primary data. For methane calculations, detailed data on animal population, feed intake, feed composition, manure excretion, and manure management practices are required to develop a custom EF.

Disaggregation methodology

Given the farm-specific nature of custom factors, they allow for the best estimation of methane emissions by source. When developing a study, companies should report emissions separately by gas and source so methane emissions from enteric fermentation, manure management, and feed production (if applicable) can be estimated. Once estimated with primary data, annual methane emissions can be expressed as an EF and applied to an inventory by dividing methane emissions by annual FPCM produced, as shown in Equation 3.

EQUATION 3

Formula for converting emissions to a methane emission factor for custom factors

$$EF_{CH_4,i} = CH_{4,i} / FPCM$$

Where:

$EF_{CH_4,i}$: *methane EF by source, i (kg* CH_4*/kg FPCM)*

$CH_{4,i}$: *methane emissions determined from custom study by source, i (kg* CH_4*)*

FPCM: total fat and protein corrected milk (kg FPCM)

Example:

The study determined that 10,000 kg CH_4 was emitted through enteric fermentation and 1,000 kg CH_4 from manure management during the study period. The group of farmers in this study produced 500,000 kg FPCM for the company. Source-specific methane EFs are developed as follows:

Enteric fermentation:

$$EF_{CH_4,EF} = 10{,}000 \text{ kg } CH_4 / 500{,}000 \text{ kg FPCM} = 0.02 \text{ kg } CH_{4,EF}/\text{kg FPCM}$$

Manure management:

$$EF_{CH_4,MM} = 1{,}000 \text{ kg } CH_4 / 500{,}000 \text{ kg FPCM} = 0.002 \text{ kg } CH_{4,MM}/\text{kg FPCM}$$

This EF can then be applied to the company's wider supply of raw milk for suppliers with similar farming systems.

While it is not as common for companies to use a custom factor as it is for companies to use a modeling tool or literature value, several companies have leveraged this method in the form of peer-reviewed LCAs, such as Fonterra[26], Organic Valley[27], and others. Given the customizable approach, custom factors are considered the best source for EFs as they can most accurately represent a company's milk supply and fully disaggregate methane emissions.

Modeling tools (better)

Modeling tools are calculation tools designed to represent a system or process and can be used to estimate GHG emissions for dairy farms. These tools rely on a combination of primary and secondary data. Depending on the data inputs and complexity of the modeling tool, they can have varying levels of accuracy and representativeness. For dairy modeling tools, typically data on geography, herd dynamics, feed inputs, manure management practices, and on-farm energy are required as inputs into the modeling tool. Emissions results are often presented by gas (CO_2, CH_4, N_2O) and emission sources (enteric fermentation, manure management, and sometimes feed production), making it easier to break out methane.

While modeling tools are generally considered a "better" source for EFs, as they are customizable and utilize primary data, they are not without their limitations. Given the complexity of dairy systems, modeling tools must rely on several assumptions, some of which may be more accurate than others. Different modeling tools may take varying calculation approaches to allocation, have more robust modeling capabilities, contain different system boundaries, or have varying abilities to incorporate emissions reduction interventions. The results output of some modeling tools may need to be supplemented or adjusted with additional data to represent a company's raw milk supply more accurately. Further, modeling tools require some level of primary data, which may not be feasible for all companies or supply chains. Despite the gaps and limitations of modeling tools, they are constantly evolving and updating their assumptions and calculations to align with new climate science and dairy modeling approaches. The purpose of this guide is not to discuss each modeling tool's limitations, rather to provide guidance on how to disaggregate methane emissions.

The section below walks through disaggregating methane for common modeling tools. All the tools listed below have the ability to disaggregate methane at some level, making them a strong choice for companies looking to disclose and prioritize methane. While this list is not comprehensive of all dairy modeling tools, it includes some of the more common tools used in the dairy industry (listed in alphabetical order). If a user's modeling tool is not listed below, the same principles of methane disaggregation can be followed if the modeling tool presents emission results by gas and source. If the modeling tool does not transparently present results, the Unknown sources section of this guide outlines how to disaggregate emissions. If a company is using multiple modeling tools, the Inventory application section walks through integrating findings between modeling tools.

CAP'2ER

Overview of emission factor source

CAP'2ER is a French-based tool that is used to evaluate and reduce environmental impacts from ruminants. The calculation methodologies are developed in accordance with FAO Livestock Environmental Assessment and Performance (LEAP) guidelines and based on IPCC Tier 1, 2, and 3 approaches. CAP'2ER assesses cradle-to-farm gate emissions and serves as a decision support tool, allowing a user to model simulations to understand reduction potentials from an action plan.

Data requirements

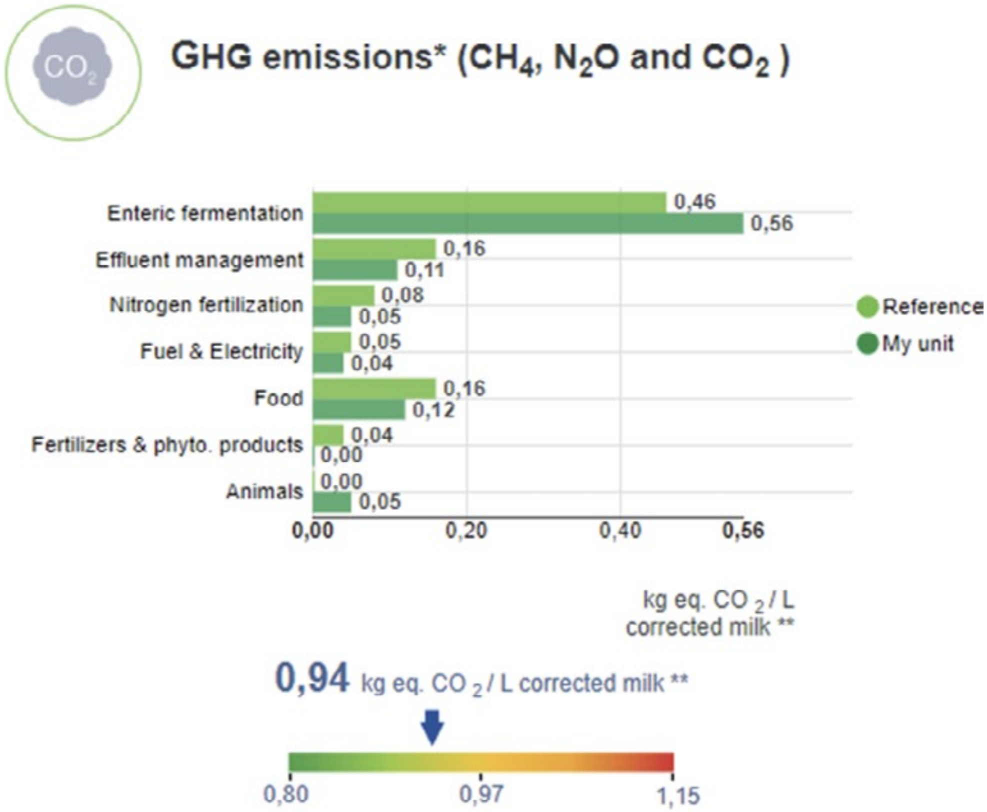
CAP'2ER uses a mix of primary and secondary data to determine total farm-gate emissions. Data input categories for CAP'2ER include herd, housing, crops, feed, and energy as well as activity data on total animals, milk production, manure management, crop production, feed rations, and on-farm energy usage.

Disaggregation methodology

CAP'2ER directly estimates methane emissions by emission source, reporting emissions in kg CO_2e/L FPCM, as shown in Figure 9. CAP'2ER users can also generate reports on total farm-level emissions broken out by gas. CAP'2ER uses a GWP100 of 27.2 to characterize methane.[28]

FIGURE 9

CAP'2ER emissions results dashboard by source



All (100%) emissions from enteric fermentation are in the form of methane, which is provided in kg CO_2e/L corrected milk. To disaggregate methane emissions from manure management, enteric fermentation emissions (kg CO_2e) must be subtracted from total farm methane emissions (kg CO_2e), as shown in Equation 4.

EQUATION 4

Formula for disaggregating methane emissions from manure management

$$Manure_{CH_4} = Farm_{CH_4} - Enteric_{CH_4}$$

Where:

$Manure_{CH_4}$ = methane from manure management (MT CO_2e)
$Farm_{CH_4}$ = total farm-level methane emissions (MT CO_2e)
$Enteric_{CH_4}$ = Enteric fermentation emissions (MT CO_2e)

A user must ensure that farm-level and enteric emissions are converted to the same units before using Equation 4. Emissions can then be converted into kg of methane by dividing by the GWP used by CAP'2ER (GWP100 = 27.2).

COMET-Farm

Overview of emission factor source

COMET-Farm is a whole farm and ranch GHG accounting tool developed by Colorado State University in conjunction with the United States Department of Agriculture (USDA) and the National Resource Conservation Service (NRCS). COMET-Farm's calculations are based on IPCC Tier 3 methodology and biogeochemical models, which are used to create Tier 2 EFs. In addition to carbon accounting, this tool allows farmers to evaluate different management options for reducing GHG emissions and increasing carbon sequestration.

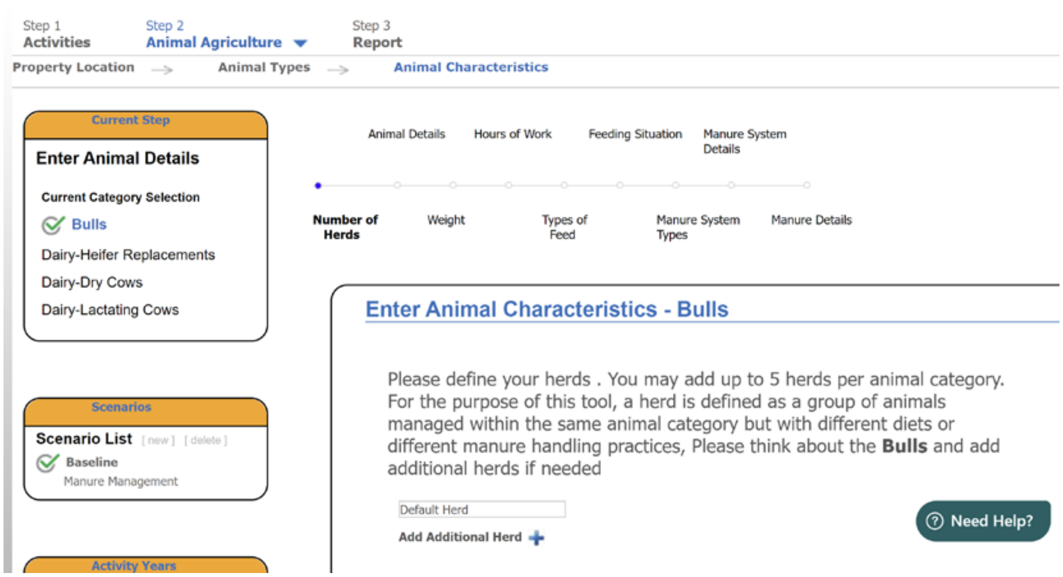
COMET-Farm has modules for cropping, animal agriculture, and forestry. To account for whole-farm emissions, the cropping and animal agriculture modules must be used together in combination with the COMET-Energy Tool, which accounts for on-farm energy use. Further, COMET-Farm only calculates direct GHG emissions for a dairy system. Indirect emissions, such as upstream production emissions from feed and fertilizers are not included in either the cropping or animal agriculture module. Thus, the system boundary is not a true cradle-to-farm gate assessment. To use COMET-Farm for a raw milk cradle-to-farm gate EF, all modules would need to be used together and upstream emissions from feed and fertilizer would need to be added to the results output.

The following sections will discuss only the animal agriculture tool, which is where dairy methane emissions are calculated and reported.

Data requirements

COMET-Farm's animal agriculture module relies on both primary and secondary data for emissions calculations. An excerpt of some of the COMET-Farm data requirements are shown in Figure 10 and include data on animal type, herd population, feed intake, animal housing, and manure management. COMET-Farm also leverages spatial data on climate and soil conditions, which allows for more site-specific carbon estimates.

FIGURE 10
Data collection requirements on COMET-Farm's dashboard



Disaggregation methodology

COMET-Farm results are reported in MT CO_2e per year broken out by herd grouping, as shown in Figure 11.

FIGURE 11
COMET-Farm animal agriculture emissions results by herd grouping

Source	Baseline Emissions
Dairy-Heifer Replacements	
Replacements	221.2
Total	**221.2**
Dairy-Dry Cows	
Dry Cows	309.4
Total	**309.4**
Dairy-Lactating Cows	
Lactating Cows	1176.6
Total	**1176.6**
Total (all animals)	***1707.2***

By double-clicking on a herd grouping, results will be broken out by gas and emission category, as shown in Figure 12. Everything below *Enteric* in the methane category would be categorized as emissions from manure management. By selecting the *Animal Ag Detailed Report,* full results can be downloaded as a comma-separated values (CSV) file.

FIGURE 12
COMET-Farm disaggregated results for dairy-lactating cows

Dairy-Lactating Cows	
Lactating Cows	1176.6
Methane *(tonnes CO2 equiv./yr.)*	1038.3
Enteric	510.5
Housing	0.0
Barn Housing	46.3
Composting	2.9
Anaerobic Lagoon	478.6
Anaerobic Digester	0.0
Nitrous oxide *(tonnes CO2 equiv./yr.)*	138.3
Housing	0.0
Composting	138.3
Anaerobic Lagoon	0.0
Total	**1176.6**

BOX 5

Disaggregating methane emissions for COMET- Farm

To determine total methane emissions from manure management in COMET-Farm results, add up the following values from Figure 12:

$$Manure_{CH_4} = Housing_{CH_4} + Barn\ Housing_{CH_4} + Composting_{CH_4} + Anaerobic\ Lagoon_{CH_4} + Anaerobic\ Digester_{CH_4}$$

Where:

$Manure_{CH_4} = 0.0 + 46.3 + 2.9 + 478.6 + 0.0 = 527.8$ *MT* CO_2e
$Enteric_{CH_4} = 510.5$ *MT* CO_2e
$Farm_{CH_4} = 527.8 + 510.5 = 1{,}038.3$ *MT* CO_2e

To express results as an EF in kg CO_2e/kg FPCM, convert annual emissions from MT to kg and divide by annual FPCM production (kg). An allocation factor to allocate between milk and meat or any other co-products generated on the farm must also be applied. Section 5.4.2, of the IDF CF standard discusses how to allocate between milk and meat on a dairy farm.

To convert this EF from CO_2e to methane, divide by the methane characterization factor used by COMET-Farm. COMET-Farm uses a GWP100 characterization factor of 25 for methane, as reported in IPCC AR4.[29] The process of converting from CO_2e to methane is described in Box 4. Note that if there is any methane from feed, it cannot be disaggregated in COMET-Farm.

Cool Farm Tool

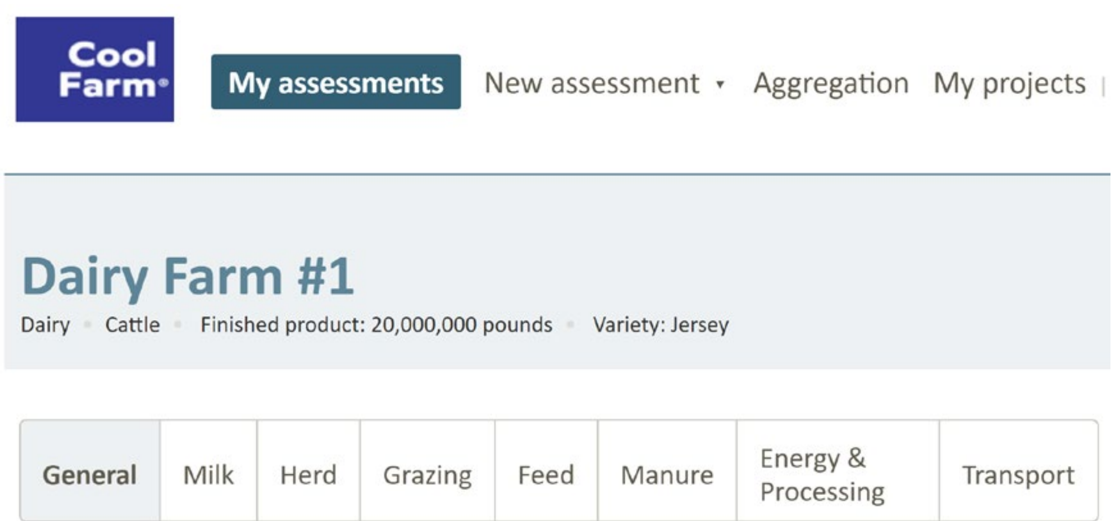
Overview of emission factor source

The Cool Farm Tool (CFT) is an online modeling tool developed by the Cool Farm Alliance that assesses farm-level GHG emissions. CFT is membership-based for corporations and free for producers. CFT provides different modules for various crops and livestock systems. Their dairy module is aligned with the IDF CF standard, with emissions calculated from cradle-to-farm gate and normalized to fat-and-protein corrected milk (FPCM).[21] The dairy module calculates emissions from grazing, grassland fertilization, feed production, enteric fermentation, manure management, energy and processing, and transport. Emission calculations are based on IPCC Tier 2 methodologies, supplemented with peer-reviewed studies and user-provided data.

Data requirements

The Cool Farm Tool uses a mix of primary and secondary data to determine total farm-gate emissions. EFs for FPCM are then derived by dividing total emissions (kg CO_2e) by total milk production (kg FPCM). Users provide data on milk production and content, herd population and weight, grazing days, grassland fertilization, feed composition and amounts, manure management practices, on-farm energy use (for dairy production only), inbound transportation of key inputs, and outbound transportation of finished products to the processing site (depending on the intended system boundary). Data entry categories for the CFT dairy assessment are shown in Figure 13. For home-grown feed, users can integrate a custom cropping assessment into the dairy assessments, applying it to their dairy feed inputs.

FIGURE 13
Cool Farm Tool dairy assessment data entry categories

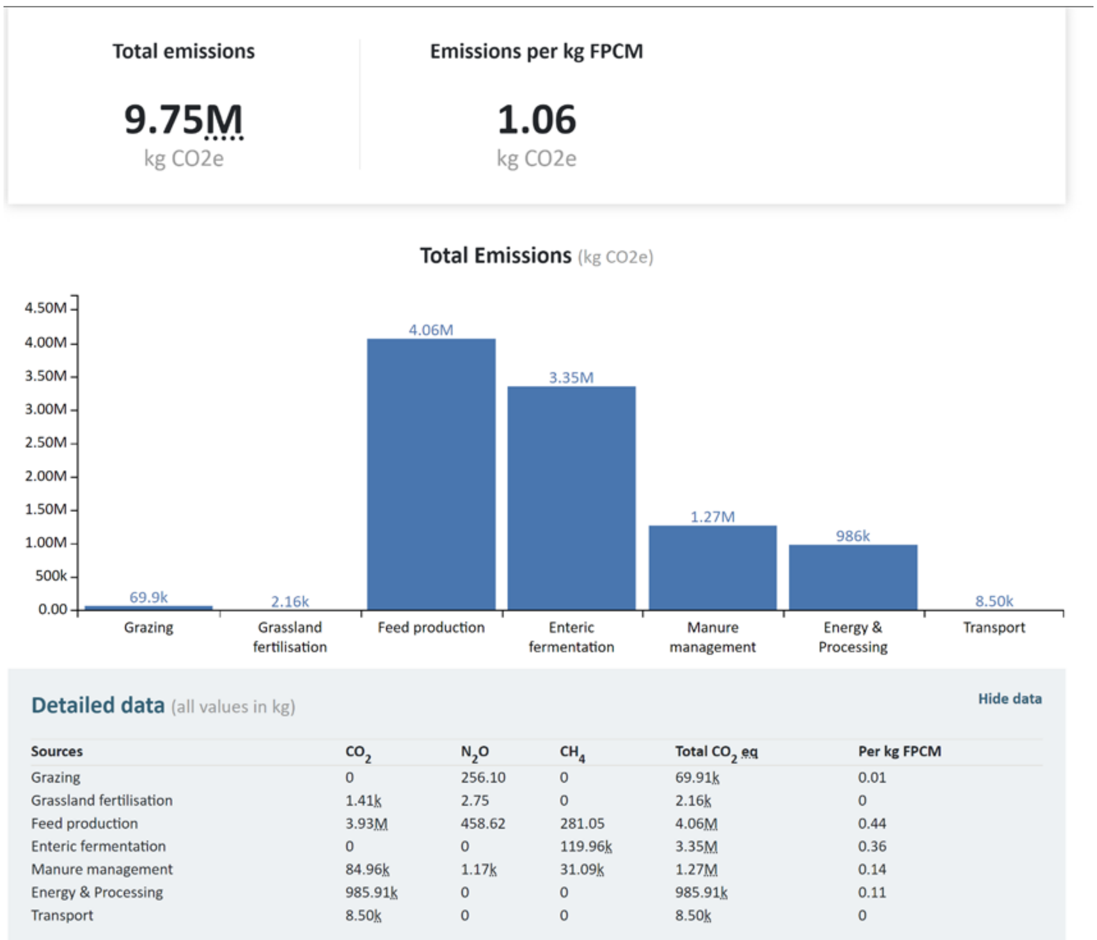


Disaggregation methodology

Cool Farm Tool directly estimates methane emissions by emission source for an individual farm assessment. Methane from enteric fermentation, manure management, and feed production (if applicable) at the farm level is displayed in the detailed results section within the tool. Figure 14 shows an example of CFT results.

FIGURE 14

Cool Farm Tool example results by gas and emission category



Sources	CO_2	N_2O	CH_4	Total CO_2 eq	Per kg FPCM
Grazing	0	256.10	0	69.91k	0.01
Grassland fertilisation	1.41k	2.75	0	2.16k	0
Feed production	3.93M	458.62	281.05	4.06M	0.44
Enteric fermentation	0	0	119.96k	3.35M	0.36
Manure management	84.96k	1.17k	31.09k	1.27M	0.14
Energy & Processing	985.91k	0	0	985.91k	0.11
Transport	8.50k	0	0	8.50k	0

Raw data for an individual farm can also be downloaded into a CSV file. Users can obtain a farm-level methane EF (in kg CH_4/kg FPCM) from the results presented in Figure 15 by adding the total methane emissions for each emission source and dividing by the total kg of FPCM produced. In this example, enteric fermentation, manure management, and feed account for 79%, 21%, and 0.2% of methane emissions, respectively.

FIGURE 15
Cool Farm Tool downloaded results for an individual farm

Farm details		
Name	Test Dairy Farm	
Country	United States of America	
Climate	Cool Temperate Moist	
Temperature	45.00	°F
Product details		
Name	Dairy Farm #1	
Variety	Jersey	
Year	2022	
Milk production	20,000,000.00	lb
Summary		
Total emissions	9,749,884.75	kg CO2e
Emissions by area	481,849.37	acre
Emissions per kg FPC	1.06	kg CO2e
Emissions per tonne	1,074.74	kg CO2e

Total emissions

Name	kg CO2	kg N2O	kg CH4	Total kg CO2e	kg CO2e per acre	kg CO2e per kg FPCM	kg CO2e per tonne
energy	985,908	-	-	985,908	19,718	0.11	108.68
enteric fermentatior	-	-	119,961	3,346,905	66,938	0.36	368.93
feed	3,931,219	459	281	4,064,265	81,285	0.44	448.01
fertilisation	1,414	3	-	2,164	43	-	0.24
grazing	-	256	-	69,914	1,398	0.01	7.71
manure	84,956	1,172	31,090	1,272,228	25,445	0.14	140.24
transport	8,500	-	-	8,500	170	-	0.94
Total emissions	5,011,997	1,889	151,332	9,749,885	194,998	1.06	1,074.75

If multiple farms within a company's supply chain are used to develop the EF, the weighted average methane emissions of all farms should be used. Cool Farm Tool's aggregated CSV results download does not provide the same level of methane disaggregation as it does for the individual farm results download. Figure 16 shows a condensed version of the data provided in the aggregated results download.

FIGURE 16

Example of aggregate Cool Farm Tool results for multiple farms

Farm	Milk	Enteric fermentation	CO_2		N_2O		CH_4	
	kg FPCM	kg CO_2e	MT CO_2	MT CO_2e	MT N_2O	MT CO_2e	MT CH_4	MT CO_2e
Farm 1	2,163,435	926,826	828	828	0.44	121	46	1,296
Farm 2	839,901	391,589	286	286	0.21	58	20	567
Farm 3	3,831,671	1,342,061	841	841	0.89	243	69	1,921
Farm 4	17,990,333	6,825,138	4,449	4,449	4.90	1,338	261	7,271
Farm 5	15,997,014	5,602,311	3,634	3,634	3.74	1,020	290	8,094
TOTAL	**40,822,354**	**15,087,925**	**10,037**	**10,037**	**10.18**	**2,780**	**686**	**19,150**

Data is provided on total milk production (kg FPCM), emissions from enteric fermentation (kg CO_2e), and total farm methane emissions (MT CH_4 and MT CO_2e). Using this data, a weighted farm-level methane EF for all farms can be derived by dividing total kg CH_4 by total kg of FPCM. This can further be broken out into methane emissions from enteric fermentation and manure management, assuming feed is not a material source of methane emissions (in this case <0.2%). All (100%) emissions from enteric fermentation are in the form of methane, which is provided in kg CO_2e. To determine methane emissions from manure management, subtract total enteric fermentation emissions (kg CO_2e) from total farm methane emissions (kg CO_2e). Emissions can be converted into kg of methane by dividing by the GWP used by CFT (GWP100 = 27.9).[30] An example of methane disaggregation for CFT results is shown in Box 6.

BOX 6

Disaggregating methane emissions for Cool Farm Tool

Using Equation 4 to disaggregate methane emissions from Figure 17:

$$\mathbf{Manure_{CH_4} = Farm_{CH_4} - Enteric_{CH_4}}$$

$Farm_{CH_4}$ = 19,150 MT CO_2e
$Enteric_{CH_4}$ = 15,088 MT CO_2e
$Manure_{CH_4}$ = 19,150 - 15,088 = 4,062 MT CO_2e

To convert these values from CO_2e to methane, divide by the methane characterization factor used by the EF source. Cool Farm Tool uses a GWP100 characterization factor of 27.9 for methane.

In the example from Figure 16, total methane emissions from each emission source are shown below:

$Enteric_{CH_4}$ = 15,088 / 27.9 = 541 MT CH_4
$Manure_{CH_4}$ = 4062 / 27.9 = 146 MT CH_4

This can be converted into a methane EF and applied to an inventory by dividing methane emissions by total farm-level milk production:

$Enteric_{CH_4}$ = 541 MT CH_4 / 40,822 MT FPCM = 0.013 MT CH_4 / MT FPCM
$Manure_{CH_4}$ = 146 MT CH_4 / 40,822 MT FPCM = 0.0036 MT CH_4 / MT FPCM

Note that given methane emissions from feed production represented ~0.2% of total methane emissions, it is excluded from the methane emissions source breakout. Methane from feed will only be significant if rice is used as a feed input. If a supplier is feeding rice, methane emissions from feed will need to be assessed at the individual farm level as it is not presented in aggregate results.

FARM ES

Overview of emission factor source

The Farmers Assuring Responsible Management (FARM) Environmental Stewardship (ES) Program, developed by the U.S. National Milk Producers Federation, is a U.S.-based modeling tool used to estimate farm-level GHG emissions and energy intensity. FARM ES Version 2 is based on a life cycle assessment (LCA) of fluid milk conducted by Thoma et al. (2013) and leverages IPCC Tier 2 methods. The system boundary is cradle-to-farm-gate with results normalized to FPCM.[31]

In 2025, FARM ES plans to fully launch Version 3 of its tool which will transition FARM ES to a "process-based" model through Ruminant Farm Systems (RuFaS). This new version will provide a more robust and accurate modeling tool than Version 2. Version 3 will also support scenario analysis to facilitate the modeling of GHG reduction plans. The data requirements and disaggregation methodology outlined below are for Version 2 of the tool. Once version 3 is released, it is expected that methane emissions can be broken out using similar methodologies outlined throughout this guide.

Data requirements

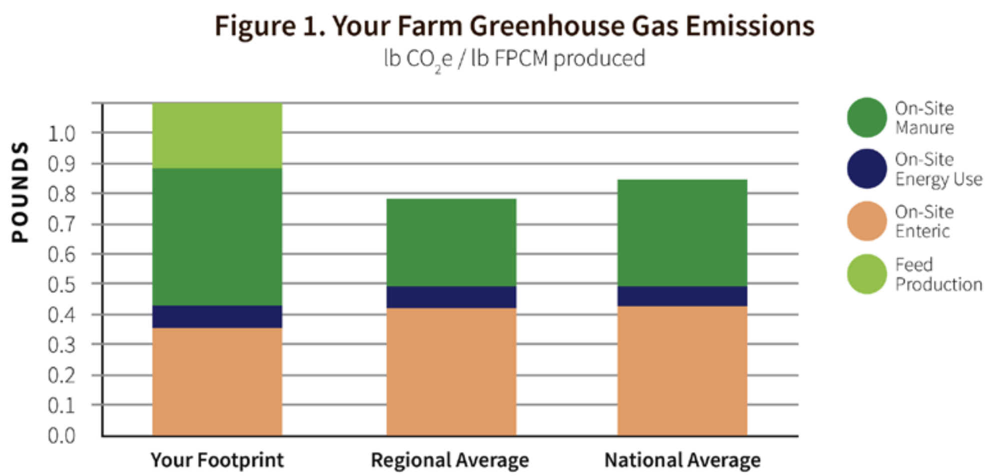
FARM ES relies on both primary and secondary data for emissions calculations. User input data on milk production records, herd population, feed rations, manure management, and energy use are required. FARM ES does not allow for the integration of farm-level crop data, but rather uses dairy LCA research to make assumptions about feed production practices based on the ration data provided. Furthermore, FARM ES does not consider specific manure application practices.

Disaggregation methodology

FARM ES provides results in lb. of CO_2e per lb. of FPCM, which can be translated to a user's desired units (e.g., MT CO_2 per MT FPCM). FARM ES results are broken out by emission category and gas type, as shown in Figures 17 and 18. Results are also compared to U.S. regional and national averages from the Thoma et al. LCA study. These data points can be a useful comparison but are not needed for disaggregating methane emissions.

FIGURE 17

FARM ES results by GHG emission category



	Your Footprint	Regional Average	Regional Difference	National Average	National Difference
Feed Production	0.187				
On-Site Manure	0.467	0.296	*-0.171*	0.358	*-0.109*
On-Site Energy Use	0.057	0.072	*0.015*	0.067	*0.009*
On-Site Enteric	0.367	0.418	*0.051*	0.431	*0.064*
TOTAL (without Feed Production)	**0.891**	**0.786**	***-0.105***	**0.856**	***-0.035***
TOTAL	**1.079**				

FIGURE 18

FARM ES results by GHG type

GAS TYPE BREAKDOWN		
Carbon Dioxide (CO_2)	**0.224 kg CO2e / kg FPCM**	**20.8%**
Methane (CH_4)	**0.524 kg CO2e / kg FPCM**	**48.6%**
Nitrous Oxide (N_2O)	**0.331 kg CO2e / kg FPCM**	**30.7%**
TOTAL	**1.079 kg CO_2e / kg FPCM**	**100.0%**

FARM ES provides a farm-level methane EF in kg CO_2e/kg FPCM, as shown in Figure 17. This can further be broken out into methane emissions from enteric fermentation and manure management. All (100%) emissions from enteric fermentation are in the form of methane, which is provided in kg CO_2e/kg FPCM. To determine methane emissions from manure management, subtract total enteric fermentation emissions (kg CO_2e/kg FPCM) from total farm methane emissions (kg CO_2e/FPCM), as shown in Box 7. To convert these values to kg methane, divide by the methane characterization factor used by FARM ES, as shown in Box 4. FARM ES uses a GWP100 characterization factor of 25 for methane, as reported in IPCC AR4.[29] Note that if there is any methane from feed, it is not able to be disaggregated in FARM ES results.

BOX 7

Disaggregating methane emissions for FARM ES

Using Equation 4 to disaggregate methane emissions from Figures 17 and 18:

$$\mathbf{Manure_{CH_4EF} = Farm_{CH_4EF} - Enteric_{CH_4EF}}$$

$Farm_{CH_4EF} = 0.524 \text{ kg } CO_2e \text{ / kg FPCM}$
$Enteric_{CH_4EF} = 0.367 \text{ kg } CO_2e\text{/ kg FPCM}$
$Manure_{CH_4EF} = 0.524 - 0.367 = 0.157 \text{ kg } CO_2e \text{ / kg FPCM}$

To convert these values from CO_2e to methane, divide by the methane characterization factor used by the EF source (FARM ES GWP = 25):

$Enteric_{CH_4} = 0.367 / 25 = 0.015 \text{ kg } CH_4 \text{ / kg FPCM}$
$Manure_{CH_4} = 0.157 / 25 = 0.006 \text{ kg } CH_4 \text{ / kg FPCM}$

GLEAM

Overview of emission factor source

The Global Livestock Environmental Assessment Model (GLEAM) was developed by the FAO to quantify the production and inputs used in livestock systems and to assess each system's GHG emissions. GLEAM follows the IPCC Tier 2 calculation methodology, reporting emissions at a regional and global scale for 11 livestock commodities. Emissions are calculated for upstream emissions (feed production, processing, and transportation), animal production emissions (enteric fermentation, manure management, and on-farm energy use), and downstream emissions (processing and post-farm transportation of livestock commodities). This is a cradle-to-processing gate system boundary.

Data requirements

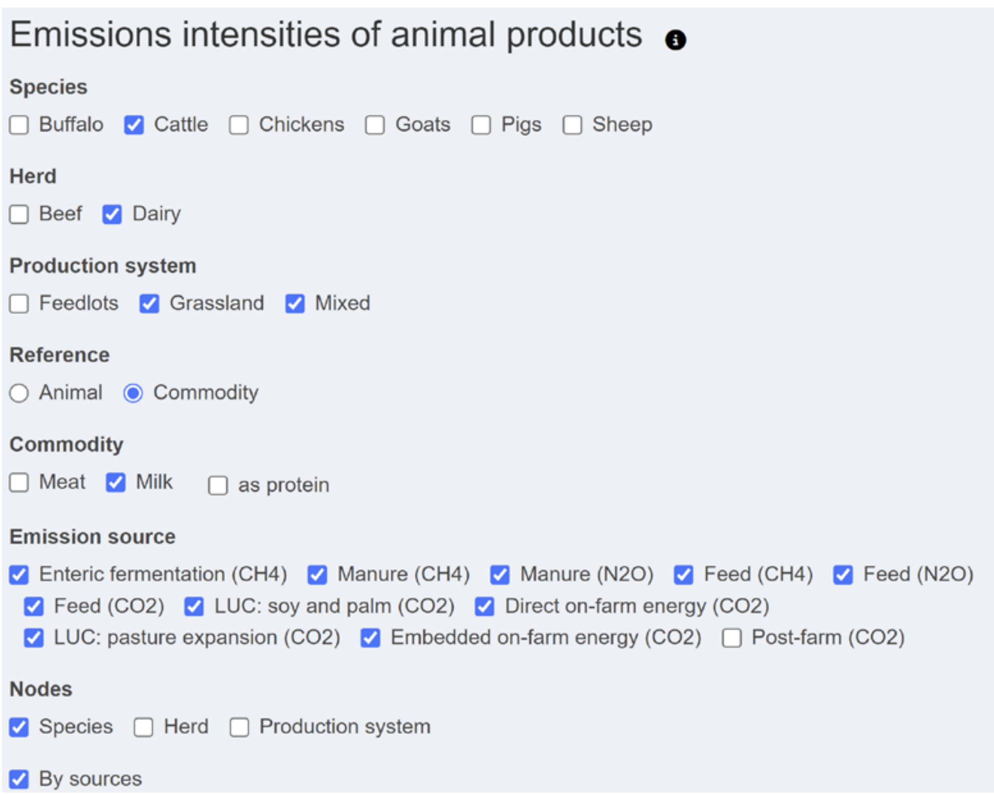
GLEAM relies on secondary data for EF development, with no primary data inputs required from the user. Regional-level data on animal numbers and distribution, herd parameters, fertilizer application rates, crop yields, milk production, manure management systems, and others are derived from literature, databases, surveys, and expert consultation. Specific database references include FAOSTAT 2015, Gridded Livestock of the World, and the Livestock Environmental Assessment and Performance

(LEAP). A user should select the criteria that best represents their system (i.e., geography and farming system).

Disaggregation methodology

GLEAM fully disaggregates the EF by gas and emission source for the selected region. Figure 19 shows the different options provided for displaying EFs on the GLEAM dashboard. The selections in the screenshot are for a cradle-to-farm-gate milk EF. Note that when assessing cradle-to-farm-gate emissions, the post-farm (CO_2) emission source should not be selected to avoid double counting in your GHG inventory. Post-farm emissions include processing and transportation/distribution, which extend beyond the farm-gate boundaries for raw milk emissions and would be calculated elsewhere in a company's inventory.

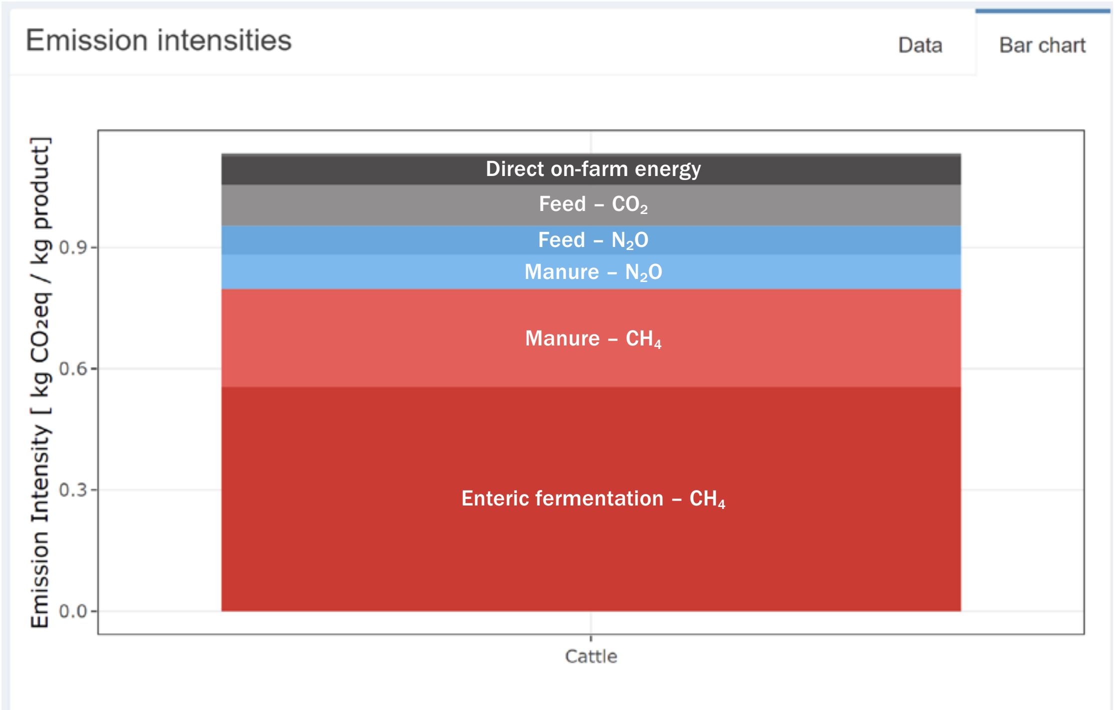
FIGURE 19
Display options for emissions intensities on the GLEAM dashboard



Selecting emissions intensity by source disaggregates the EF by emissions source, as shown in Figure 20. While GLEAM has an option to select Feed (CH_4), data is not available for this metric, as methane emissions from feed are assumed to be immaterial.

FIGURE 20

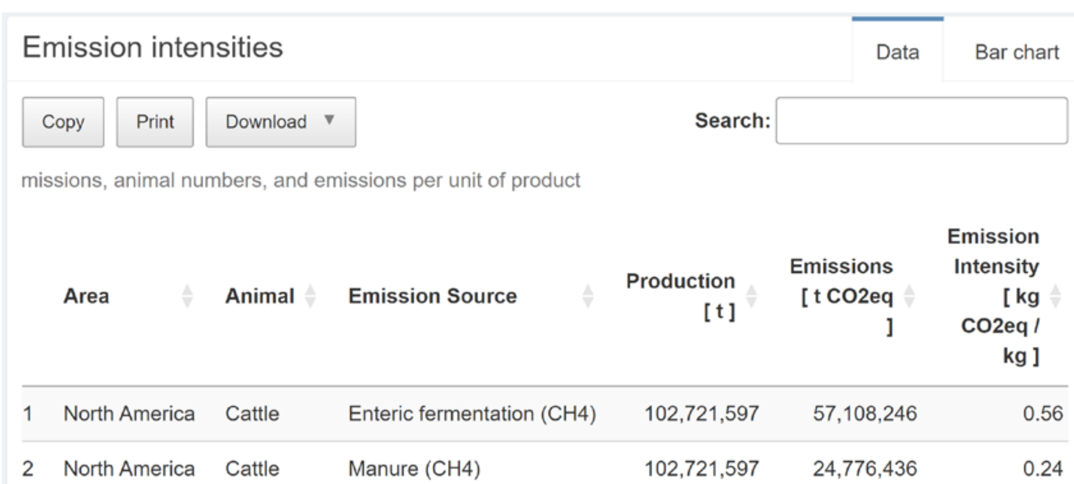
Results of GLEAM emissions intensity of FPCM for North America



Raw data can be viewed and downloaded in the data tab, as shown in Figure 21, and can be directly applied to a GHG inventory. Methane emissions are provided in CO_2e using a 100-year period for the GWP dataset selected by the user. IPCC AR6 is the default selection and uses a methane characterization factor of 27. To convert kg CO_2e to kg methane, divide by the selected methane characterization factor.

FIGURE 21

Methane emissions from enteric fermentation and manure management for North American FPCM



	Area	Animal	Emission Source	Production [t]	Emissions [t CO2eq]	Emission Intensity [kg CO2eq / kg]
1	North America	Cattle	Enteric fermentation (CH4)	102,721,597	57,108,246	0.56
2	North America	Cattle	Manure (CH4)	102,721,597	24,776,436	0.24

Holos

Overview of emission factor source

The [Holos modeling tool] is a software application that estimates GHG emissions and soil carbon changes for Canadian farming systems. It has scenario capabilities, where users can assess the impact of certain interventions on their GHG emissions and soil carbon. Holos is based on IPCC Tier 2 calculation approaches and leverages Canadian national databases for soil and NASA climate data. The dairy component can be combined with the land management component to incorporate crop and hay production into a farm-level GHG assessment.

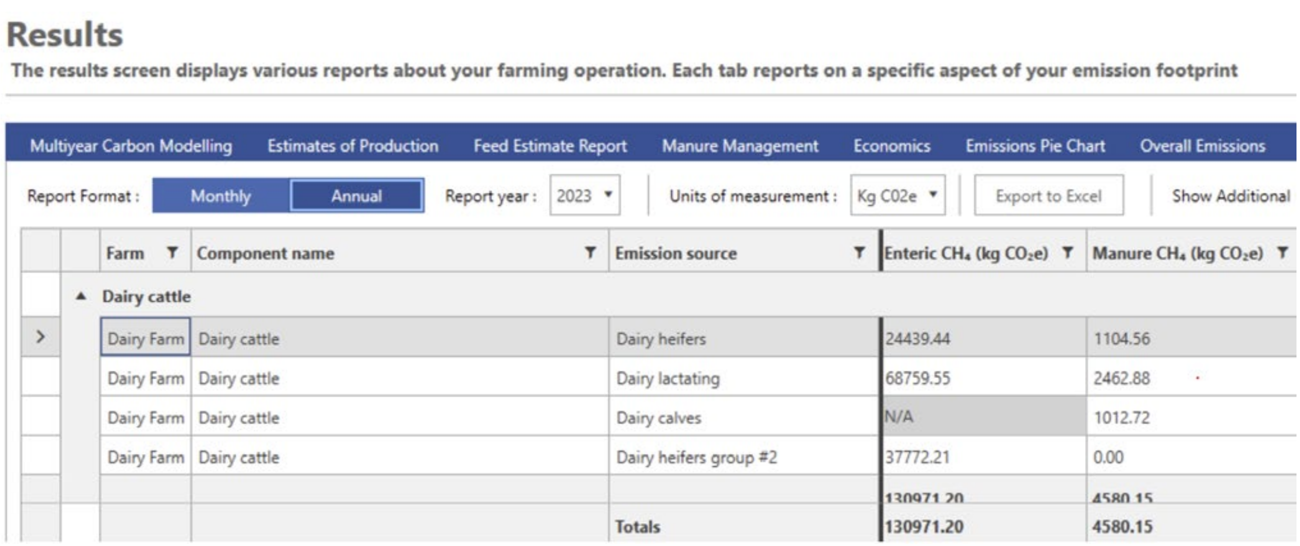
Data requirements

Holos uses a mix of primary and secondary data to determine total farm-gate emissions. Data input categories include location data, land management practices for cropping, number of animals, animal housing, manure systems, and diet for each animal grouping. Holos is set up to calculate a farm's GHG budget rather than a carbon footprint, meaning it accounts for all farm-based emissions that can be estimated based on available data. To calculate the carbon footprint of raw milk, feed production must be fully accounted for by adding feed-producing fields to the simulated farm and the total area of crop fields required to feed the dairy herd. Holos will generate a warning message if not enough feed is being grown to satisfy animal requirements. In addition to ensuring total feed requirements are included, results must be related back to kg of FPCM as discussed in the disaggregation methodology section below.

Disaggregation methodology

Holos fully disaggregates emissions by gas and source in their detailed emissions report, as shown in Figure 22. Emissions are provided in either kg CO_2e or kg CH_4 for enteric fermentation and manure management. Users should view emissions in kg CH_4 rather than kg CO_2e to view disaggregated methane emissions.

FIGURE 22
Excerpt of Holos results for dairy methane



Farm	Component name	Emission source	Enteric CH_4 (kg CO_2e)	Manure CH_4 (kg CO_2e)
Dairy cattle				
Dairy Farm	Dairy cattle	Dairy heifers	24439.44	1104.56
Dairy Farm	Dairy cattle	Dairy lactating	68759.55	2462.88
Dairy Farm	Dairy cattle	Dairy calves	N/A	1012.72
Dairy Farm	Dairy cattle	Dairy heifers group #2	37772.21	0.00
			130971.20	4580.15
		Totals	130971.20	4580.15

Results are provided as total farm-level emissions and must be related back to FPCM to create an EF for a company to use in its GHG inventory. This can be done by dividing the emissions by total kg FPCM produced during the data collection period and applying an allocation factor for milk and meat or any other co-products generated on the farm. Section 5.4.2, of the IDF CF standard discusses how to allocate between milk and meat on a dairy farm.

Literature values (good)

Literature values for dairy EFs are derived from peer-reviewed studies, most commonly life cycle assessments (LCAs) or product carbon footprints (PCFs) of dairy farming systems and products. Literature values are a source of secondary data.

As of 2022, there have been over 4,800 peer-reviewed studies on the carbon footprint of dairy products and farming systems.[21] Given the wide range of studies, the data quality, representativeness to a company's own system, and capability to break out methane varies significantly from study to study. EFs derived from literature values can range from better to good to poor data sources depending on a variety of factors. It is possible to find a study that contains high-quality data, represents a company's own system, and provides disaggregated results. However, because of the lack of customization and primary data, across the board, literature values are considered a "good" source of EFs, when compared to custom factors and modeling tools.

When selecting a study, it is important that the user assesses data quality, representativeness, and granularity of results. At a high level, the user should ensure that the geography selected represents the company's regional milk supply, as EFs can vary widely from country to country.[7] Similarly, different farming systems and manure management practices can result in varied emissions. The literature study selected should match the geography and farming system of a company's milk supply when possible. Users should also prioritize studies that break out emissions by gas and source when possible.

The following sections walk through disaggregating methane for literature values, including LCA databases, LCA studies, and spend-based data. The capability to disaggregate methane will vary widely based on the literature value selected, with some results fully breaking out emissions by source and gas and others providing little to no granularity into the gases or sources that make up the EF. The Unknown sources section of this guide outlines how to disaggregate emissions if a literature value selected does not transparently present results. If a company is using multiple literature values or a combination of literature values and modeling tools, the Inventory application section walks through integrating findings between EF sources.

LCA database, activity data (e.g., ecoinvent, WFLDB)

Overview of emission factor source

LCAs are a method for evaluating the environmental impact of a product throughout its entire life cycle. They are composed of a collection of activity data, known as a life cycle inventory (LCI) with a set system boundary, most commonly cradle-to-gate (farm or processing) or cradle-to-grave. A full cradle-to-grave LCA includes data for raw material extraction, processing, distribution, use, and disposal. Cradle-to-gate system boundaries contain activity data that stops at the farm or processing gate. An LCA database is a collection of LCI data used to complete LCAs. These databases contain information on inputs, outputs, emissions, energy and material flows, resource consumption, and environmental impacts for raw materials and finished goods for many goods and services across various sectors, including agriculture, construction, materials, electronics, transportation, etc. The datasets included in an LCA database are robust and typically provide a high level of data transparency and quality. They can be analyzed using LCA software to assess a range of environmental impacts, including global warming potential (GWP). Common LCA databases containing dairy activity data include ecoinvent, AgriFootprint, World Food LCA Database, AGRIBALYSE (a French database), The Big Climate Database (a Danish consequential LCA database), and others.

Data requirements

LCA databases are a form of secondary data and do not require primary data inputs from the user. When using an EF from an LCA database, the user should select the dataset that most accurately represents their supply chain, ensuring the appropriate system boundary, production system, and geography is selected. For example, a company purchasing organic milk from a French dairy should aim to select a cradle-to-farm gate study of raw milk from an organic French dairy, ideally operating in the same region in France. Additionally, selecting a database representative of farm size, feed composition, and manure management practices will provide a more representative EF. When possible, companies should use the same database across their inventory. However, for companies with diverse supply chains, this may not be possible, as a single database may only have data on specific production systems or geographies not reflective of a company's supply chain. If the system boundary of the study goes beyond the farm gate, the user should ensure the results are presented granularly enough to understand and extract the cradle-to-farm gate impact.

Disaggregation methodology

LCA software tools allow a user to manipulate and analyze LCA databases, allowing methane to be easily disaggregated by gas and often by source. The most common software tools are SimaPro, Sphera (formerly known as GaBi), and openLCA. User licenses are required for SimaPro and Sphera. A number of open-source LCA software programs are free to download and use, including openLCA, Activity Browser, and Brightway.

To disaggregate methane using LCA software, the process should first be analyzed using IPCC 2021 GWP100. This methodology uses a GWP characterization value of 27 for biogenic methane, as reported in IPCC AR6.[23] LCA software also allows a user to analyze data using other GWPs (e.g., IPCC 2021 GWP20). In order to disaggregate emissions by source, a unit process must be used, which will assess the impact at each input level (e.g., manure, fertilizer, feed, etc.). In contrast, a system process will aggregate the LCA results and does not allow a user to view results by input (i.e., methane source). Analysis results are displayed in kg CO_2e. Results can be viewed by characterization, which will break out emissions into biogenic, fossil, and land transformation emissions. Biogenic emissions include biogenic methane emissions.

The granularity of results and ability to fully disaggregate methane emissions by source will depend on the LCA database that is selected. Some databases fully disaggregate methane by input source, while others may combine methane from enteric fermentation, manure management, and feed as a direct emission to air. World Food LCA Database fully separates enteric fermentation and manure management as inputs into the process, allowing the user to clearly view the disaggregation in the impact assessment results. A simplified example results table from LCA software is recreated in Figure 23. Note that the inputs listed in the World Food LCA Database analysis results may be listed with different input names. The "GWP100-biogenic" row is the biogenic methane emissions for each input, broken out by enteric emissions and manure management. Emissions can be converted into kg CH_4 by dividing by the methane characterization used for the analysis, 27 for IPCC 2021 GWP100.

FIGURE 23

Example impact assessment results for 1 kg raw milk broken out by input

Impact Category	Unit	Total	Raw milk	Enteric emissions	Manure Management	Maize silage	Electricity
GWP100 – fossil	kg CO_2e	0.310	X	X	0.105	0.152	0.039
GWP100 – biogenic	kg CO_2e	0.752	X	0.580	0.171	0.001	X
GWP100 – land transformation	kg CO_2e	0.103	X	X	X	0.091	X

Agri-footprint and AGRIBALYSE separate out biogenic methane by source as direct emissions to air in the LCI data, as shown in Figure 24. This data is reported in kg of CH_4 / kg product. When referencing a database that breaks out emissions in this way (e.g., Agri-footprint and AGRIBALYSE), a user does not need to further analyze the results through the LCA software, as the methane is already disaggregated by source. In Figure 24, the methane EF for enteric fermentation is 0.038 kg CH_4 / kg FPCM, and the methane EF for manure management is 0.00541 kg CH_4 / kg FPCM (storage and grazing).

FIGURE 24

Example emissions to air for 1 kg FPCM

Emissions to air	Amount	Unit	Comment
Ammonia	0.0035	kg	Emissions due to manure storage
Dinitrogen monoxide	0.000041	kg	Direct N_2O due to storage
Methane, biogenic	0.038	kg	Enteric CH_4 emissions
Methane, biogenic	0.0052	kg	Emissions of CH_4 from manure storage
Methane, biogenic	0.00021	kg	Emissions of CH_4 during grazing

Ecoinvent provides the lowest level of disaggregation as it combines biogenic methane for manure management and enteric fermentation as emissions to air in the unit process, allowing the user to disaggregate emissions by gas but not by methane source. While the methodology and capability to break out emissions by methane source varies between databases, all LCA databases allow the user to disaggregate emissions by gas when analyzing the LCA results.

LCA study (academic journal article)

Overview of emission factor source

LCA studies are typically peer-reviewed studies published in academic journals. As discussed above, LCA studies can range in data quality, representativeness, and data transparency. It is important to assess this when selecting an EF from an LCA study.

Data requirements

LCA studies are a form of secondary data and require no data inputs from the user. When selecting the study, it is important to ensure the study most accurately represents the user's supply chain, production method, geography, and intended system boundary (e.g., cradle-to-farm gate). Furthermore, because there is little ability to manipulate or dissect the results of an LCA study, it is important to ensure the desired assessment method (e.g., IPCC GWP100) is used. When possible, the user should select a study where the results are already disaggregated by gas and emission source.

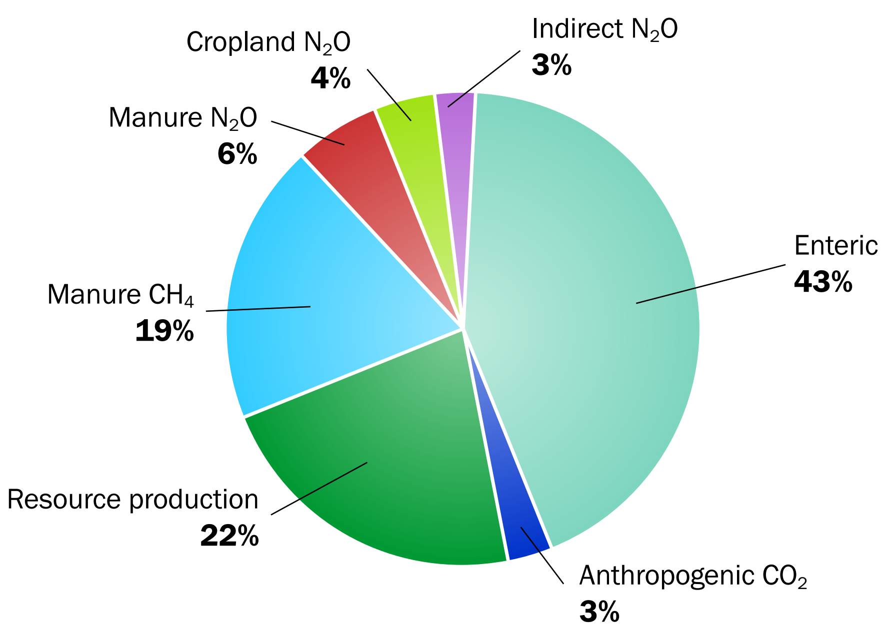
Disaggregation methodology

The ability to accurately disaggregate an EF derived from an LCA study will depend on the study selected and the level of granularity in which the data is presented in the results section. Some studies explicitly break out methane emissions by source and gas. More frequently, studies break out enteric fermentation emissions, but not methane from manure management. This section will walk through three examples for how to disaggregate milk EFs from different LCA studies. If the study does not break out emissions by either gas or source, refer to the methodology outlined in the Unknown sources section.

Disaggregating methane dairy emissions from "Environmental assessment of United States dairy farms" study

"Environmental assessment of United States dairy farms" by Rotz et al. is a cradle-to-farm gate LCA of six different dairy production systems across six U.S. geographical regions.[9] Results are reported in kg CO_2e/kg FPCM and aggregated at a regional and national level. Figure 25 shows results disaggregated by emission source and gas for the national average, where methane from enteric fermentation and manure management accounts for 43% and 19% of total emissions, respectively. Methane from feed is not broken out as it is not a material source of methane emissions.

FIGURE 25
U.S. national average raw milk GHG emissions contribution by source and gas[39]



To determine methane emissions, these percentages can be applied to the national EF of 1.01 kg CO_2e/kg FPCM provided in the study, then converted to methane using the characterization factor for methane stated in the study, which in this case is 25. This example calculation is outlined in Equation 5.

EQUATION 5

Formula for disaggregating methane emissions for literature values using percentages

$$EF_{CH_4,S} = EF_{Farm} \times CH_4\%_S$$

Where:

$EF_{CH_4,S}$ = *methane EF by source, s (kg CO_2e/kg FPCM)*
EF_{Farm} = *cradle-to-farm gate EF (kg CO_2e/kg FPCM)*
$CH_4\%_S$ = *Percent of emissions attributed to methane by source, s (%)*

Example:

Rotz et al. study results shown in Figure 25:
EF_{Farm} = *1.01 kg CO_2e/kg FPCM*
$CH_4\%_S$ = *43% for enteric fermentation and 19% for manure management*

Enteric fermentation: $EF_{CH_4,EF}$ = *1.01 kg CO_2e/kg FPCM × 43% = 0.43 kg CO_2e/kg FPCM*
Manure management: $EF_{CH_4,MM}$ = *1.01 kg CO_2e/kg FPCM × 19% = 0.19 kg CO_2e/kg FPCM*

To convert these values from CO_2e to methane, divide by the methane characterization factor used by the emission factor source, in this case 25.

Disaggregating methane dairy emissions from "The evolution of the carbon footprint of Dutch raw milk production between 1990 and 2019" study

Hospers et al. conducted a cradle-to-farm gate analysis of the carbon footprint of raw milk for the average Dutch dairy system between 1990 and 2019 using national statistics and farm data from the Dutch Farm Accountancy Data Network (FADN).[32] This study provides an example literature value for a raw milk EF for the Netherlands. The results are reported in g CO_2e / kg FPCM for each year from 1990 to 2019 and disaggregated by emission source. In this study, emissions sources include on-farm roughage production, enteric methane, purchased resources, manure storage and stable, energy, and other.

Since 100% of enteric emissions are in the form of methane, this is fully disaggregated and can be converted into kg CH_4 using Equation 5. This study uses a characterization factor of 27.2 for biogenic methane. Once converted to kg CH_4, a company can apply this EF to its methane inventory.

Manure management is also reported in g of CO_2e and is not broken out by gas. Since manure management includes both nitrous oxide and methane emissions, a user must estimate the emissions attributed to methane using proxy data. Since this study represents the average Dutch dairy production system, the FAO GLEAM dataset is an appropriate proxy to use to estimate manure management emissions from methane. If the selected study is specific to a single manure management system, the proxy being used should be reflective of that system. Equation 6 walks through how to disaggregate methane from manure management emissions using a proxy, with Hospers et al. as an example.

EQUATION 6

Formula for disaggregating methane from manure management emissions using a proxy

$$\textit{MM EF}_{CH_4} = \textit{Lit MM} \times (\textit{Proxy MM}_{CH_4} / \textit{Proxy MM}_{Total})$$

Where:

$\textit{MM EF}_{CH_4}$ = *Methane EF from manure management in g* CO_2*e/kg FPCM*
Lit MM = Total EF from manure management in g CO_2*e/kg FPCM*
$\textit{Proxy MM}_{CH_4}$ = *Methane emissions from manure management in proxy in kg* CO_2*e/kg FPCM*
$\textit{Proxy MM}_{Total}$ = *Total emissions from manure management in proxy in kg* CO_2*e/kg FPCM*

Example:

The raw milk EF factor provided in Hospers et al. is 992 g CO_2e/kg FPCM for 2019. In Appendix D of the study, emissions are segregated by source, with enteric fermentation accounting for 415 g CO_2e/kg FPCM and manure management accounting for 132 g CO_2e/kg FPCM. It is assumed that feed is not a significant source of methane emissions for Dutch dairy systems.

Enteric fermentation:

Since enteric fermentation emissions are all in the form of methane, this can be converted into kg CH_4 using the characterization factor reported in the study, 27.2:

$$\textit{EF } CH_4 = 415 \text{ g } CO_2\text{e/kg FPCM} / 27.2 \text{ kg}CO_2\text{e/kg } CH_4 / 1{,}000\text{g/kg} = 0.015 \text{ kg } CH_4\text{/kg FPCM}$$

Manure management:

Since manure management is not broken out by gas, a proxy must be used to estimate manure management emissions. Since this study represents average manure management systems across the Netherlands, the FAO GLEAM dataset can be used as a proxy. The FAO-reported dairy emissions data includes a high level of regional granularity. For this study, the Western Europe region would be used. The following formula can be used to estimate methane from manure management:

Using Equation 6, manure management emissions from methane from Hospers et al. are estimated to be:

$$\textit{MM EF}_{CH_4} = 132 \text{ g } CO_2\text{e/kg FPCM} \times (0.21 \text{ kg } CO_2\text{e/kg FPCM}/ 0.32 \text{ kg } CO_2\text{e/kg FPCM}) = 86.6 \text{ g } CO_2\text{e/kg FPCM}$$

This can then be converted into kg CH_4 / kg FPCM using the characterization factor reported in the study, 27.2:

$$\textit{MM EF}_{CH_4} = 86.6 \text{ g } CO_2\text{e/FPCM} / 27.2 \text{ kg } CO_2\text{e/kg } CH_4 / 1{,}000\text{g/kg} = 0.003 \text{ kg } CH_4\text{/kg FPCM}$$

In this example, methane emissions from enteric fermentation and manure management account for 42% and 9% of total emissions, respectively. Once EFs are broken out by source and gas and converted into kg CH_4, they can be applied to a company's inventory.

Disaggregating methane dairy emissions from "Variation in the carbon footprint of milk production on smallholder dairy farms in central Kenya" study

Wilkes et al. conducted a cradle-to-farm gate study on the carbon footprint of milk production on smallholder dairy farms in central Kenya to assess the variability between feeding systems, allocation approaches, and GWPs used.[33] This study assessed data from 382 dairy farms and represents a regional average EF for central Kenya milk production. It is one example of an EF for smallholder dairy farms in Eastern Africa.

As this study assesses the impact of varying allocation methods and GWPs, it is important that the user select those that most closely match their accounting approach. The study reports raw milk emissions to be 2.56 kg CO_2e/kg FPCM when GHG emissions were allocated between milk and meat based on their protein content, using GWP from IPCC 2013: 28. In section 4.2 on sources of GHG emissions, the study also notes that 55.5% of total GHG emissions were from enteric fermentation and 12.6% of emissions from manure management.

Since enteric fermentation is 100% methane, kg of CH_4 can be determined by multiplying the farm-gate EF by the percent attributed to enteric fermentation and converting this value into kg CH_4. See Equation 5 for calculation details. A proxy must be used, however, to determine what portion of manure management emissions are methane. Since this study represents the average manure management system for central Kenya, FAO GLEAM values for Eastern Africa would serve as a good proxy. Users should first multiply the farm-gate EF by the percent attributed to manure management and then follow the calculation approach outlined in Equation 6.

LCA database, spend-based data (e.g., U.S. EPA EEIO, Exiobase)

Overview of emission factor source

Spend-based EFs are based on environmentally-extended input-output (EEIO) models, which combine environmental and economic indicators to estimate emissions resulting from the production of upstream supply chain activities for different economic sectors. This results in an EF that relates the financial value of a good or service to its corresponding emissions in the form of GHG emissions per dollar spent. The USEEIO model and Exiobase are common databases for spend-based EFs.

Spend-based EFs are most often used in Scope 3 GHG screening exercises. It is not recommended for a company to use this method for their full inventory since these EFs represent broad sector averages and may not reflect a company's specific processes or products. Spend-based EFs can often be dated, not fully reflecting the current supply and demand or inflation, and are limited to certain geographies. They also do not allow companies to model the impact of different farm-level interventions on GHG emissions without reducing spending since spend-based EFs are tied to an economic measure (e.g., Euros spent on raw milk each year) rather than a physical one (e.g., kg of FPCM purchased each year).

Unless the database explicitly provides disaggregation by gas, methane cannot be disaggregated from spend-based EFs since the data is based on spend and not milk production. If the database does provide disaggregation by gas, sources are not typically transparent and cannot be translated to emissions sources. If a company uses spend-based EFs to calculate dairy emissions, it is recommended that they move to activity-based emission factors, as discussed above.

Unknown sources

Overview of emission factor source

EFs derived from an unknown source or from a source lacking data transparency might be used when a supplier, stakeholder, or parent company provides a raw milk EF with little context. Further, it is possible the source of an EF could not be traced from prior versions of a company's inventory. The "unknown source" methodology may also be used when an EF with a traceable data source does not fully disaggregate methane emissions (e.g., literature values). This section will discuss how to break out methane emissions in these scenarios. However, before proceeding with this methodology, companies should work with suppliers and stakeholders to determine the source of the EF when possible. Only when it cannot be determined should this methodology be used.

If a supplier or other stakeholder provides an EF without transparency or unknown data quality, it is advised to cross-check the EF with existing data before using it in an inventory. EFs can be assessed and compared to existing literature values based on the appropriate region, farming system, system boundary, and time period to determine if they are appropriate to use. Regional-level GLEAM EFs outlined in the Modeling tools section are often a good place to start for cross-checking EFs. Once the EF has been cross-checked, the following disaggregation methodology can be used to determine approximate methane emissions.

This is the least desirable method for breaking out methane emissions as it provides an even more generalized estimation of methane emissions. Companies should always seek transparent EFs with high-quality data when possible. Section 5.1 of the IDF CF standard outlines data quality criteria and recommendations.[21]

Disaggregation methodology

To disaggregate methane from EFs with an unknown source, a percentage approach can be applied to the EF. This approach applies the total percentage of methane emissions in a proxy to the EF. It is important that the proxy selected is representative of the appropriate geography and farming system. GLEAM EFs are often good proxies because methane is fully disaggregated by source, percentages can easily be applied, and data are available for many geographies. Figure 26 shows North America's GLEAM raw milk factor applied to an unknown source. Note that methane from feed is not included here as it is assumed to be an immaterial source of methane emissions.

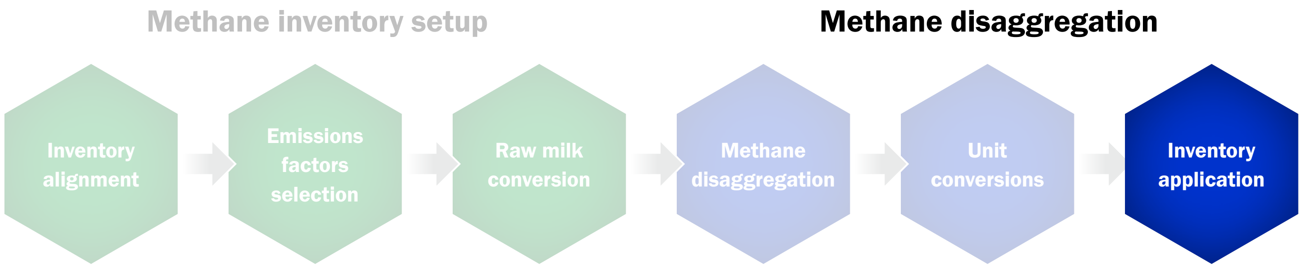
FIGURE 26.
Using a proxy to estimate methane emissions from an unknown emission factor source

Emission factor	**Total emissions** (kg CO_2e/kg FPCM)	**Enteric CH_4 emissions** (kg CO_2e/kg FPCM)	**Manure CH_4 emissions** (kg CO_2e/kg FPCM)
Proxy emission factor	1.13	0.56	0.24
Proxy percentages	100%	49.6%	21.2%
Unknown source emission factor	1.40	1.40 * 0.496 = **0.69**	1.4 * 0.212 = **0.30**

Once methane emissions are estimated, emissions can be converted into kg CH_4 by dividing by the IPCC GWP100 methane characterization factor of 27 (AR6), as shown in Box 4.

Inventory application

FIGURE 1.5
Methane GHG inventory development process: Inventory application



Once methane is disaggregated for all raw milk EFs and the units are converted into kg CH_4, the next step is to apply these EFs to a GHG inventory to determine total methane emissions.

For complex supply chains, multiple EFs representing different regions, production systems, and dairy products may be needed to complete a company's GHG inventory. These EFs may leverage varying levels of primary data and utilize different calculation methodologies. As such, multiple methane disaggregation methodologies will need to be used for companies using more than one EF.

For example, a company may source both organic and conventional milk, applying different EFs for each farming system. These EFs might come from different sources to best represent the farming systems from which the milk is sourced. For example, the organic supply might use a modeling tool while the conventional supply might use a literature value.

As discussed in the Unknown sources section, multiple EFs may also need to be used for EFs with unknown sources or for sources not able to fully disaggregate methane emissions. In those cases, a proxy is used in conjunction with the chosen EF for the inventory.

Once methane is disaggregated from each EF using the methods discussed above, Equation 7 can be applied to determine total methane emissions.

EQUATION 7

Applying methane emission factors to an inventory

$$CH_{4_{TOTAL}} = \sum RM_i * EF_{CH_4,\, i}$$

Where:

$CH_{4_{TOTAL}}$ = aggregated methane emissions
RM_i = mass of raw milk purchased from a given farming system, i (kg)
$EF_{CH_4,\, i}$ = methane EF for a given farming system, i (kg CH_4/kg FPCM)

Example:

A company has three suppliers for raw milk and uses a different EF to best represent each milk supply. They source 20,000 kg of conventional FPCM from a supplier in the Netherlands and use a literature study to calculate emissions. They source 10,000 kg of organic FPCM from a supplier in France and use CAP'2ER to calculate emissions. They source 20,000 kg of conventional milk from a supplier in France and use GLEAM to calculate emissions.

Using the disaggregation methodology provided in the section above, the methane emissions were determined for each source:

Raw milk supply	Enteric fermentation CH_4 EF (kg CH_4 / FPCM)	Manure management CH_4 EF (kg CH_4 / FPCM)
Netherlands conventional supply	0.019	0.006
France organic supply	0.027	0.008
France conventional supply	0.023	0.007

Using the formula above, company methane emissions were calculated as follows:

Methane emissions from enteric fermentation:

$$(20{,}000 \times 0.019) + (10{,}000 \times 0.027) + (20{,}000 \times 0.023) = 1{,}110 \text{ kg } CH_4$$

Methane emissions from manure management:

$$(20{,}000 \times 0.006) + (10{,}000 \times 0.008) + (20{,}000 \times 0.007) = 340 \text{ kg } CH_4$$

IDENTIFYING METHANE HOTSPOTS

IDENTIFYING METHANE HOTSPOTS

Once a company has developed its methane inventory, identifying the hotspots is a crucial step in developing a broader strategy for a dairy methane action plan. A "hotspot" can be defined as an area within a company's GHG inventory with disproportionately high GHG emissions. Locating these hotspots can help guide a company's action plan, allowing mitigation interventions to focus on high methane-emitting areas of its supply chain and, thus, GHG inventory.

How to identify methane hotspots

Hotspots should be determined by analyzing the relative contribution of different emissions (or methane) sources to total GHG emissions. Hotspots are influenced by product volume and product emission factors (EFs). For example, a dairy processor might source 10,000 MT of raw milk with an EF of 1.1 kg CO_2e/kg raw milk and 100 MT of butter with an EF of 10.5 kg CO_2e/kg raw milk. Even though the EF for butter is 10 times that of raw milk, its emissions make up less than 10% of the company's total emissions from dairy products. Based on absolute emissions contribution, the company should focus its reduction strategies on raw milk suppliers before expending efforts on butter suppliers.

Additional information on hotspot identification more generally can be found in EDF+ Business Report Pathways to Net Zero: The Decisive Decade.

Metrics for identifying hotspots

Analyzing inventory data to identify hotspots will depend on the level of data granularity that is available. Companies can take a multifaceted approach and consider multiple data points when identifying hotspots. Below are the types of data a company can assess to identify hotspots:

- **Regional:** Analyzing data at the regional level can allow companies to prioritize regions that have the most emissions, whether this is influenced by total volume sourced or country-specific factors such as farm size/efficiency, manure management practices, or feed composition.
- **Product type:** Data can also be assessed by product type, where dairy products with the highest sourcing volume and methane emissions would be identified as hotspots.
- **Emission source:** Methane can be further assessed by emission source – enteric fermentation, manure management, feed, and dairy waste – where mitigation strategies might center around enteric fermentation, which is known to be the greatest source of emissions.
- **Supplier:** Data can also be analyzed by supplier, where supplier sourcing volume and supplier EFs could be the focus.
- **Others:** Other company-specific factors may be used to identify hotspots.

Across all categories, the level of influence a company holds on areas of the supply chain should also be assessed. If a company has minimal control over a region, product, or supplier, it may not be effective to center reduction strategies on these areas given the lack of influence. A company often has greater influence on its direct suppliers and less influence on suppliers further upstream.

Common dairy methane hotspots

As discussed throughout this guide, enteric fermentation and manure management are the largest sources of dairy methane. Together, they account for over half of the total emissions from raw milk and nearly all methane emissions from the dairy sector. For this reason, companies should focus their methane reduction strategies on these two key sources. The forthcoming Dairy Methane Action Alliance Dairy Methane Action Plan (DMAP) guide addresses common farm-level methane reduction strategies within the dairy sector, focusing mainly on enteric fermentation and manure management.

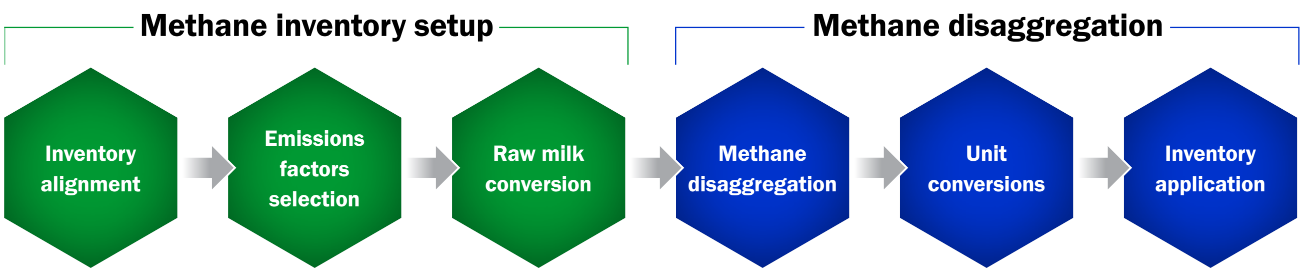
CONCLUSION

CONCLUSION

Reducing methane can significantly impact global warming over the next few years, and the time to act on methane is now. Given that methane comprises approximately 60% of dairy emissions, the dairy industry has a significant opportunity to reduce its methane impact and slow global climate change in the near term. To act on this, dairy companies must be equipped with the tools to measure and report their methane emissions publicly.

This guide has provided an approach for dairy companies to set up their inventory for methane disaggregation and separate out methane emissions from total emissions depending on their raw milk emission factor sources.

FIGURE 1
Methane GHG inventory development process



In doing so, companies can more easily identify hotspots, develop targets, and implement strategies to reduce methane emissions.

Forthcoming Dairy Methane Action Alliance guidance documents will provide a framework for dairy sector companies to publicly disclose their methane emissions, develop a methane-specific action plan for companies to reduce methane from dairy production, and engage with their suppliers and stakeholders to implement their action plan.

FIGURE 2
Dairy Methane Action Alliance (DMAA) initiative trajectory

As all these guidance documents will build upon accurately accounting and reporting methane emissions, this first step is crucial for a company looking to take action and reduce its dairy methane emissions.

APPENDICES

APPENDICES

Appendix 1: Food loss emissions

Overview of food loss accounting

From a GHG accounting perspective, any upstream cradle-to-farm gate emissions from organic wastes are captured in the raw milk emission factor (EF). Waste generated during raw milk processing is reported in Scope 3 Category 5 of the GHG Protocol (Waste Generated in Operations).[34] Downstream waste from distribution, retail, and consumers, are accounted for in Scope 3 Category 12 (End-of-Life Treatment of Sold Products).[35]

Given that this guide is geared toward dairy processors and/or producers, this guide will cover 1) on-farm milk loss, which is already embedded within the cradle-to-farm gate carbon footprint of purchased milk, and 2) food and fiber waste generated in a processor's operations, which is covered in this section. Producers and processors have the most control over their own operations and are thus better equipped to account for and reduce methane emissions in these areas. While methane emissions from end-of-life treatment of sold products are impactful, they are outside the scope of DMAA.

Data requirements

To assess methane emissions from waste generated in operations, the total mass of organic waste from milk products, including both food and fiber-based packaging, is required. Ideally, this is primary data collected during processing or factory waste audits. Disposal methods for all material categories are also needed.

Disaggregation methodology

This section will walk through a simplified disaggregation method for Scope 3 Category 5, Waste Generated in Operations for a company to report and disclose on methane emissions generated in its operations.

Methane emissions from dairy waste generated in operations can be calculated by multiplying the mass of each waste category by the methane EF for each disposal method, as shown in Equation 8.

EQUATION 8

Formula for emissions generated from operational dairy waste

$$CH_{4W} = \sum(DFW * \%DM * EF_{CH_4;\,DM}) + \sum(FPW_{Dairy} * \%DM * EF_{CH_4,DM})$$

Where:

CH_{4W} = methane emissions from operational dairy waste, in kg CH_4
DFW = mass of dairy food waste in kg
$\%DM$ = percent of waste sent to each disposal method
$EF_{CH_4;\,DM}$ = methane EF for disposal method in kg CH_4/kg
FPW_{Dairy} = mass of fiber-based packaging waste associated with dairy products in kg

Waste amounts by material type and percentage of waste sent to various disposal methods should be identified by the company through waste audits. The methane emissions of disposal methods vary widely, with landfilling of organic waste releasing the most methane due to the anaerobic conditions. The EPA estimates that for every 1,000 tons (907 metric tons) of food waste landfilled, 34 metric tons of methane emissions are released.[36] This results in an EF of 0.04 kg CH_4/kg organic waste, or 1.08 kg CO_2e/kg organic waste. However, this can vary widely depending on waste composition, landfill characteristics, and climatic conditions.

In contrast, methane emissions are significantly reduced when composting organic waste. Methane emissions vary based on the conditions of the composting facility. Nordahl et al. conducted a meta-analysis on 46 different studies and found average methane emissions from the composting of organic food waste to be 8.79×10^{-4} kg CH_4 / kg food waste.[37] If other disposal methods are employed, industry average methane EFs should be used for each disposal method. Box 8 walks through an example calculation.

BOX 8

An example of calculating methane emissions from food loss generated in operations

A company generates 1,000 MT of dairy food waste during its processing operations each year. Of the total dairy food waste generated, 50% is sent to the landfill, 30% to a composting facility, and the remaining 20% to a local pig farm and used for feed. The company also generates 100 MT of fiber waste from packaging materials for its dairy products. All of this fiber waste is sent to a recycling facility.

This company uses the “recycled content method” for allocation, meaning the disposal emissions from the recycling process are allocated to the user of the recycled content.[34] Further, there are no emissions allocated to the company when the food waste is used as feed. This company’s Category 5, methane emissions from dairy would be as follows:

$$CH_4w = (1{,}000\ MT \times 50\% \times 0.04\ MT\ CH_4/MT) + (1{,}000\ MT \times 30\% \times 8.79X10^{-4}\ MT\ CH_4/MT) + (1{,}000\ MT \times 20\% \times 0\ MT\ CH_4/MT) + (100\ MT \times 30\% \times 0\ MT\ CH_4/MT) = 20.3\ MT\ CH_4$$

In this example, nearly 99% of methane emissions are from the landfilling of food waste and 1% are from composting.

Appendix 2: Default dry matter content of dairy products

The the table below is taken from Annex 5 of the European Dairy Association (EDA) Product Environmental Footprint Category Rules (PEFCR) for Dairy Products.

Default values for main dairy products

Liquid milk

	Whole milk	Semi-skimmed milk	Skimmed milk
Average dry matter (g/100g)	12.3	10.5	9.1

Dried whey products

	Whey (unspecified)	Thin Whey	Thick Whey	Whey Powder	Lactose Powder	Whey protein concentrate (WPC)	Whey protein isolate powder	High fat whey protein concentrate powder
Average dry matter (g/100g)	6.8	4.8	26.5	96.5	99.8	94	95	98

Cheeses

	Fresh cheese	Soft cheese	Semi-hard cheese	Hard cheese
Average dry matter (g/100g)	23	49	59.9	66

Fermented milk products

	Spoonable, plain	Spoonable, flavoured	Spoonable, fruited
Average dry matter (g/100g)	12.2	20.6	23.3

Butterfat products

	Butter, unsalted	Butter, salted	Dairy spreads
Average dry matter (g/100g)	84.4	84.1	42.7

Additional values for specific dairy products

Milk and whey	*Average dry matter (g/100g)*
Raw milk	12.5
Milk, skimmed, UHT pasteurized	9.1
Milk, semi-skimmed, pasteurized	10.7
Milk, semi-skimmed, UHT pasteurized	10.3
Milk, whole, UHT pasteurized	12.3
Whey sweet fluid	6.8
Buttermilk natural	10.0
Buttermilk flavoured	16.8

Cheeses	*Average dry matter (g/100g)*
Cottage cheese 40% fidm, made of whole milk	21.4
Petit-Suisse type cheese 20% fidm, plain, made of half-skimmed-milk	18.2
Ricotta cheese	26.5
Uncured cheese product, low-fat	30.3
Uncured cheese spread 40% fidm, salted, 13% fat	34.1
Mozzarella cheese	42.6
Quark, fresh cheese, 20% fidm	20.5
Quark, fresh cheese, 40% fidm	26.1
Fresh cheese, 50% fidm	40.7
Cheese spread, light	25.9
Cheese spread	33.5
Uncured cheese spread 60% fidm, salted, 42% fat	52.0
Mascarpone	54.7
Camembert and similar cheese 50% fidm, 26% fat	49.1
Manchego cheese	59.7
Edam cheese	58.3
Maasdam cheese	59.1
Tomme cheese	58.2
Raclette cheese	58.0
Gouda cheese	58.9
Cheddar cheese	63.3
Processed cheese 25% fidm, 15% fat	41.1

Cheeses *con't*	***Average dry matter (g/100g)***
Processed cheese 45% fidm, 22% fat	48.9
Processed cheese snack with breadsticks, for children	57.4
Emmental cheese	63.8
Gruyere cheese	65.5
Comté cheese	68.5
Cheese Stilton	63.8
Parmesan cheese	73.8
Parmigiano cheese	69.1
Provolone cheese	62.0
Pecorino cheese	66.5
Blue cheese	54.7
Asiago	67.5
Bel paese	54.5
Gorgonzola	60.0
Grana	67.5
Munster	57.0
Tilsit	49.0

Dried products	***Average dry matter (g/100g)***
Milk, semi-skimmed, dried	96.4
Milk, skimmed, dried	96.0
Milk, whole, dried	96.8
Whey sweet dried	96.4

Fermented milk products	***Average dry matter (g/100g)***
Yoghurt, low fat, plain	11.4
Yoghurt, nonfat, plain	10.7
Yoghurt, whole milk, plain	12.2
Fermented milk, whole milk, Bifidus, plain	13.5
Yoghurt, whole milk, with cream, plain	16.7
Yoghurt, low fat, with fruit	19.9
Fermented milk, whole milk, Bifidus, flavoured, sweetened	20.6

Fermented milk products *con't*	***Average dry matter (g/100g)***
Yoghurt, whole milk, with fruit	23.1
Fermented milk, whole milk, Bifidus, with fruit	24.8
Yoghurt, whole milk, with cream, flavoured	25.8
Yoghurt, Greek	21.7
Kefir	12.0
Yogurt Bulgarian - cow's full fat milk	11.8
Yogurt Bulgarian - sheep's full fat milk	16.5
Yogurt Bulgarian - buffalo's full fat milk	16.0
Yogurt Bulgarian - goat's full fat milk	11.0

Butterfat products and cream	***Average dry matter (g/100g)***
Butter spread, low-fat 60-62% fat, salted (0,5-3%)	60.5
Butter spread, low-fat 60-62% fat	63.3
Butter, unsalted	84.4
Butter, salted (0,5-3%)	84.1
Cream, "light", 8% fat, thick or fluid	17.4
Cream, fluid, 15-20% fat, UHT pasteurized	24.1
Cream, fluid, 30% fat, UHT pasteurized	37.6
Cream, 38% fat	42.4
Dairy spread 25% fat	31.2
Dairy spread, 39-41% fat	45.2
Dairy spread, 39-41% fat, salted (0,5-3%)	49.0
Single cream	23.0
Whipping cream	45.5
Double cream	53.1
Clotted cream	67.8
Extra thick cream	31.0
Crème fraiche	44.2

Data sources

Ciqual	FR	https://pro.anses.fr/TableCIQUAL/
NEVO	NL	http://www.rivm.nl/
SFK	DE	http://www.sfk-online.net/
DTU	DK	http://www.foodcomp.dk/
BEDCA	ES	https://www.bedca.net/
BDA	IT	http://www.bda-ieo.it/
coF IDS	UK	http://tna.europarchive.org/
del Prato	IT	Ottavio Savlvadori del Prato, “trattato di Tecnologia Casearia”
IDF Bulgaria	BL	Bulgarian National standard for BULGARIAN YOGURT
Uokik	PL	Data based on the "Report on consumers and food stuff market" December 2009 httop://uokik.gov.pl

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