METHANE MITIGATION SOLUTIONS

Overview

This section of the guide provides an overview of available and upcoming methane mitigation solutions. Key solutions are evaluated using a set of 13 different criteria. Given the number of solutions for methane mitigation, emerging and novel solutions that are less well studied are not fully evaluated but are outlined in Appendix 4. Appendix 5 includes further information on dairy processing improvements that can reduce methane emissions from dairy waste. While the lists of solutions presented throughout this guide are a comprehensive look at dairy-methane-reducing interventions, they are not exhaustive of all solutions in the marketplace.

This section first presents all identified solutions in Table 2. Evaluation criteria for key solutions are then defined and used to rank or categorize each solution by the different criteria parameters, highlighting which solutions are most accessible and ready for implementation, among other characteristics. Presenting different mitigation solution types can help companies identify which solutions best fit their operations and supply chains and estimate methane reductions associated with different strategies and actions. It is important to note that companies must still perform their own due diligence to understand how applicable each solution is to their own operations and supply chains and whether they can maintain the solution over time to realize the benefits in the long term.

TABLE 2

List of methane mitigation solutions

EDF and Ceres do not endorse specific solutions or the research associated with each solution.

Mitigation pathway	Mitigation solution	Solution description	Table in report
Enteric emissions reductions	3-NOP (e.g., Bovaer®)	A synthetic compound added to feed that acts as a methane inhibitor.[a]	Table 3. Full evaluation
Enteric emissions reductions	*Asparagopsis sp.* (e.g., Brominata®, Methane Tamer™, SeaFeed™, SeaGraze®, SeaStock)	A bromoform-containing red seaweed feed additive that acts as a methane inhibitor.[a]	Table 3. Full evaluation
Enteric emissions reductions	Breeding/genetics improvements for CH_4 (e.g., Semex®)	Selective breeding for methane efficiency traits.	Table 3. Full evaluation
Enteric emissions reductions	Diet optimization	Employing a variety of techniques to optimize the proper mix of forage and grain, such as selection of feed type and quality, introduction of legumes and tannin-rich plants, balance of starch, and phase feeding.	Table 3. Full evaluation
Enteric emissions reductions	Essential oils (e.g., Agolin®, Mootral Enterix™)	A feed additive made from an essential oil blend that acts as a rumen modifier.[a]	Table 3. Full evaluation
Enteric emissions reductions	Feed storage/quality	Implementing the proper storage of feed to retain feed quality and improve feed digestibility.	Table 3. Full evaluation
Enteric emissions reductions	Lipid supplementation	Supplementing feed with additional plant oils, such as olive, sunflower, and linseed oils, or tallow.	Table 3. Full evaluation

Mitigation pathway	Mitigation solution	Solution description	Table in report
Enteric emissions reductions	Methane capture headpiece (e.g., ZELP)	A CH_4-oxidizing device that converts CH_4 to CO_2 and water. The device also tracks animal health and wellness and is being piloted as an enteric methane measurement tool.	Table 3. Full evaluation
Enteric emissions reductions	Methane vaccines (e.g., ArkeaBio™, Lucidome Bio)	Vaccine to reduce ruminant methane emissions.	Table 3. Full evaluation
Manure management	Anaerobic digesters	Airtight structure that breaks down manure in the absence of oxygen and allows for the capture of biogas.[3]	Table 3. Full evaluation
Manure management	Composting	The aerobic decomposition of manure by microorganisms in a managed system, which can be achieved by a variety of composting methods, including compost bedded packs. Methane reduction occurs when compost is routinely and continuously turned over.[2]	Table 3. Full evaluation
Manure management	Daily spread	Removing manure from the barn and applying it to cropland or pasture daily.[2] This requires soil testing to ensure nutrients are not being over applied and manure is not being applied near water bodies.	Table 3. Full evaluation
Manure management	Manure additives: Acidification	Treating manure piles or lagoons with acid, most commonly sulfuric acid. There are emerging studies on the use of bio-acids such as sucrose, glucose, and whey. The acidic environment reduces net GHGs and ammonia emissions.	Table 3. Full evaluation
Manure management	Manure cover and flare systems	Airtight covers that collect biogas and flare it off as CO_2. This includes primary lagoons and secondary lagoons where anaerobic digestate is stored.	Table 3. Full evaluation
Manure management	Manure operational improvements	Employing a variety of techniques to optimize manure management, such as leak prevention, regular removal, and timing and method of manure application.	Table 3. Full evaluation
Manure management	Manure separators	Solid-liquid separation of manure: solids to bedding or compost, liquids to anaerobic digester or (preferably covered) storage lagoon.	Table 3. Full evaluation
Manure management	N2 Applied	The plasma treatment of manure reduces ammonia and methane while producing nitrogen-rich organic material.	Table 3. Full evaluation
Manure management	Pasture-based management	Incorporate pasture-based management as a strategy for manure management, including practices such as rotational grazing, adjusting grazing timing based on grass maturity, and optimizing stocking rates to evenly distribute manure on pasture and enhance nutrient cycling.	Table 3. Full evaluation
Productivity optimization and milk intensity reduction	Activity trackers	Automated health monitoring systems and the use of AI and computer monitoring to track and improve animal health.	Table 3. Full evaluation
Productivity optimization and milk intensity reduction	Animal health improvements	Use of animal health solutions for the prevention, treatment, and control of animal conditions to enhance productivity, improve animal welfare, and increase longevity.	Table 3. Full evaluation
Productivity optimization and milk intensity reduction	Breeding/genetics improvements for yield	Selective breeding to improve productivity and yield.	Table 3. Full evaluation
Productivity optimization and milk intensity reduction	Herd management/stocking density	Controlling barn stocking density for an optimal ratio of cows to stalls or cows to pasture. Too high of stocking density can lead to animal health concerns, while too low of stocking density may not maximize productivity.	Table 3. Full evaluation
Productivity optimization and milk intensity reduction	Herd management/young stock optimization	Focused management of early rearing of calves to optimize health and growth rate, reducing time to optimum weight for first calving.	Table 3. Full evaluation
Productivity optimization and milk intensity reduction	Robotic milking	Robotic or automatic milking systems allow for voluntary milking of cows, which increases productivity. These systems can also track robust data on milking frequency and milk quality.	Table 3. Full evaluation
Enteric emissions reductions	Acetic-acid-producing bacteria	Emerging research to replace the methane-producing microbes in the rumen with an acetic-acid-producing bacteria found in baby kangaroo feces.[4]	Table 5. Emerging solutions

Mitigation pathway	Mitigation solution	Solution description	Table in report
Enteric emissions reductions	Bioengineered feed additives (e.g., Lumen Bioscience, Elysia Bio)	Early-stage research on feed additives made from bioengineered products, such as spirulina (algae), corn grain, rye grass, and sorghum.	Table 5. Emerging solutions
Enteric emissions reductions	Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR)	Early-stage research to apply CRISPR genome-editing technology to methane-producing microbes.	Table 5. Emerging solutions
Enteric emissions reductions	Macroalgae (excluding *Asparagopsis sp.*)	Feed additives derived from non-bromoform-containing seaweeds, such as the phlorotannin-containing brown seaweeds.[5]	Table 5. Emerging solutions
Enteric emissions reductions	Nitrates	Supplementing feed with nitrate, which serves as a hydrogen sink in the rumen, reducing methane production. Further studies are needed to ensure that increased ammonia production does not outweigh the benefits of added nitrates.	Table 5. Emerging solutions
Enteric emissions reductions	Polyphenols (e.g., Polygain™)	Supplementing feed with naturally occurring polyphenols, such as tannins found in plants.	Table 5. Emerging solutions
Enteric emissions reductions	Probiotics (e.g., Hoofprint Biome)	Probiotics and natural enzymes as a feed additive.	Table 5. Emerging solutions
Enteric emissions reductions	Synthetic bromoform (e.g., Rumin8)	Synthetically-derived bromoform feed additive with the same active compound found in *Asparagopsis sp.* (tribromomethane/bromoform), acting as a methane inhibitor.	Table 5. Emerging solutions
Enteric emissions reductions	Yeast cultures (e.g., Yea-Sacc®)	A feed additive derived from yeast cultures that acts as a rumen modifier, while enhancing yield and promoting animal health.	Table 5. Emerging solutions
Manure management	Manure additives: *Asparagopsis sp.*	Application of *Asparagopsis sp.* to manure piles.	Table 5. Emerging solutions
Manure management	Manure additives: Biochar application	Application of biochar to manure piles.	Table 5. Emerging solutions
Manure management	Manure additives: SOP Lagoon	A powdered additive, primarily composed of gypsum, used in the treatment of liquid manure management systems.	Table 5. Emerging solutions
Manure management	Manure additives: Tannins	Application of naturally occurring tannins found in plants to manure piles.	Table 5. Emerging solutions
Manure management	Manure drying	Drying of manure through solar drying or in closed drying systems.	Table 5. Emerging solutions
Manure management	Manure pasteurization	Raising the temperature of liquid manure in storage to greater than 70 °C to reduce biological activity of microbes.	Table 5. Emerging solutions
Manure management	Pyrolysis	Heating of manure in oxygen-limited environment to convert into carbon-rich biochar.	Table 5. Emerging solutions
Manure management	Vermicomposting for manure management	The use of vermiculture (worms) to break down organic matter.	Table 5. Emerging solutions
Dairy processing improvements	Manufacturing optimization	Optimizing manufacturing to reduce dairy waste.	Table 6. Dairy waste solutions
Dairy processing improvements	Ultra-pasteurization	Ultra-pasteurizing milk to extend the shelf life of dairy products.	Table 6. Dairy waste solutions
Dairy processing improvements	Waste diversion	Diverting dairy waste from landfills to alternate waste streams, such as composting, animal feed, or anaerobic digestion.	Table 6. Dairy waste solutions

[a] Feed additives are often classified as either methane inhibitors or rumen modifiers. Methane inhibitors directly block the methanogenesis process, inhibiting the formation of methane. Rumen modifiers alter the rumen environment to suppress methane production.