Climate-smart practices to reduce greenhouse gas emissions from dairy farms

The following practices seek to reduce the emission of two potent greenhouse gases (GHGs), methane and nitrous oxide. Methane is produced in cow rumens and during anaerobic manure decomposition. Nitrous oxide is emitted during nitrogen (N) cycling in soil and in manure storage units. Dairies also have GHG emissions associated with inputs used in the farm, e.g., synthetic N fertilizer and fuel. Practices that reduce N fertilizer usage can be credited with emission reductions.

A practice is "climate-smart" if it achieves absolute emission reductions compared with the status quo or current practices. Calculating an emission reduction requires establishing a farm's baseline GHG emissions related to a practice and comparing them with emissions under new management. This is critical, as establishing this effect allows commercializing agricultural climate commodities. Applying a practice without participating in carbon markets may render environmental benefits but does not align with the project goals; CARAT seeks to translate GHG reductions into economic gains for producers via market mechanisms that can stand on their own. Practices solely enhancing productivity and reducing emissions per unit output (e.g., per unit of milk) without absolute emission reductions are not eligible. If CARAT funded practices enable getting premiums for low-carbon footprint milk, producers can benefit from these premiums. However, the primary goal of the project is to accomplish and commercialize reductions in GHG emissions.

Soil carbon storage is not a CARAT priority due to the uncertainty of storage rate estimations and the vulnerability of soil organic carbon to future losses. These factors increase verification costs and may reduce carbon dioxide equivalent prices. However, documented net carbon storage from practices such as enhanced rock weathering or other practices can be considered for funding.

Practices not listed here but proposed by other parties undergo evaluation by a CARAT team under the following guidelines to determine if the practice is climate smart: 1) Existing evidence indicates that the practice has GHGs benefits; and 2) the fundamental science of GHG emissions indicates a practice warrants consideration or further testing. When necessary, and if resources permit it, a practice can be subject to further research and monitoring when evidence is absent. While not all ideas can be evaluated, CARAT aims to foster innovation and assess the merit of each practice objectively.

The list of practices below is subject to review. To enable funding by the program, each practice must correspond to a specific NRCS Practice Code. NRCS Practice Code numbers that may correspond with each practice are noted in parentheses. The climate smart practices will need to be aligned to specific protocols to allow participation in carbon offset and inset markets.

1) Reduction of enteric methane emissions

The application of these climate-smart practices requires input from dairy nutrition experts that will be part of the Climate Smart Dairy Team that will work with each producer. In all cases, expected emission reductions must be scientifically proven and exceed a practice-specific threshold.

Table 1. Practices to reduce enteric methane emissions

Practice (NRCS code)	**Description**	**Expected benefit**
Feed additives that suppress methane emissions. (592)	Using approved feed additives that inhibit methane formation in the rumen, such as 3-nitrooxypropanol (Bovaer; approved by FDA 05/28/2024).	Reduced methane emission. Effectiveness depends on the feed additive and on following a strict protocol. Scientifically proven expected emission reductions > 10% are eligible for funding.
Various plant-based additives and plant extracts. (592)	Manipulate rumen fermentation and inhibit or stimulate various groups of microbes.	Minimal (5%) reduction in methane emissions, scientifically proven.
Asparagopsis-based products. (592)	Bromoform, the active compound in Asparagopsis inhibits the last step in rumen methanogenesis. Not approved for use in the US yet.	Methane emission reduction of up to 20-40%.
Feeding highly digestible forages or grain. (592)	Redesign of diet to increase the proportion of highly digestible forages and/or starch. Examples: increase the proportion of corn silage (as opposed to alfalfa or grass silages) and/or increase the proportion of concentrates in the diet. Rumen acidosis and milk fat depression must be avoided.	Reduced methane emission. Effectiveness depends on the magnitude of diet change compared with the baseline. It requires expert input from nutritionist. Diet change may imply land use change, which needs to be accounted for.
Increasing the proportion of lipids in the diet. (592)	Adding the proper balance of lipids can reduce methane production. Rumen acidosis and milk fat depression must be avoided.	Reduced methane emission. Effectiveness depends on the magnitude of diet change compared with the baseline. It requires expert input from nutritionist.

Table 1. Cont'd

Nitrates (592)	Electron and hydrogen sink, takes hydrogen away from methanogenesis.	Methane emission reduction of up to 10-20%. Extreme caution must be exercised when administering nitrates. Animals should be properly adapted and re-adapted, if nitrate supplementation is temporarily discontinued. Access to molasses blocks with nitrate should be limited to prevent nitrate poisoning. Unwise to use when diets have high crude protein concentrations. Practice requires expert input from nutritionist and veterinarian.

2) Reduction of methane emissions from manure management

Table 2. Practices that reduce methane emission from manure management*

Practice (NRCS code)	Description	Expected benefit
Cover anaerobic manure storage unit and flare methane (cover and flare). (313, 367, 371, 372)	Installation of impermeable covers on top of manure storage units with capture and flare of methane.	Reduced methane emission.
Separation of liquid and solids in manure. (632)	Mechanical separation of the liquid and solid fractions of manure allows using the solid fiber for compost or bedding, thus reducing carbon sources entering anaerobic manure storage and methane production.	Reduced methane emission. Solid portion of the manure recycled for bedding material thus reducing production costs.
Manure acidification (NA)	Addition of acid (e.g., sulfuric acid) to manure to reduce pH to around 6. The acidification suppresses methane production. No NRCS practice code assigned; not eligible for funding, yet.	Methane emission reduction of up to 70%.
Composting of manure. (313, 317, 367, 561)	Aerobic decomposition of manure in either a stand-alone facility or coupled with animal housing as a compost bedded pack facility.	Aerobic decomposition of manure limits methane emission. Aerobic compared to anaerobic decomposition of manure reduces methane emissions.
Frequent land application of manure to reduce storage time. (590)	Spread manure more frequently in accordance with a nutrient management plan. Focus on warm seasons when anaerobic methane production is greater. Manure must be applied to land with perennial or annuals crops as nutrient sink.	Reduced time of manure in anaerobic conditions that lowers methane production.

*Digestors are not funded through this program

3) Reduction of nitrous oxide emissions

The application of these climate-smart practices requires input from soil fertility experts that will be part of the Climate Smart Dairy Team that will work with each producer.

Table 3. Practices to reduce nitrous oxide emissions

Practice name	Description	Expected benefit
Generic reduction of nitrogen (N) inputs (590)	Evaluation of the farm N balance and documented reduction in synthetic N application rate. This generic practice needs to be associated to specific practices or technologies described below that enable N application rate reductions without a yield penalty.	Up to 50% nitrous oxide emission reduction. Benefits accrued from reduced cost and from the commercialization of climate commodities. Increasing the ratio of N harvested to N applied reduces nitrous oxide emissions.
Reduction of N inputs by using Penn State N Recommendation Tool or a comparable and verified tool (590)	Total N rate applied (synthetic fertilizer and manure combined) equals the economic optimum N rate recommended by the Penn State N Recommendation Tool for corn or a comparable tool for corn or other crops. Site-specific; pre-plant soil sampling and manure analyses are often required. https://extension.psu.edu/soil-organic-matter-and-cover-crop-based-nitrogen-recommendations-for-corn	Benefits accrued from reduced cost and from the commercialization of climate commodities. Fertilizer N application rates and nitrous oxide emissions are reduced by using site-specific information.
Reduction of side-dress N inputs informed by pre-sidedress nitrate test (PSNT) or a comparable tool (only for fields with manure history). (590)	Sidedress N fertilizer rate applied to corn field informed by the PSNT test. Similar methods for other crops apply. Soil samples must be taken from individual fields when corn is about 12” tall: https://agsci.psu.edu/aasl/soil-testing/pre-sidedress-nitrate-test-for-corn-psnt	Benefits accrued from reduced cost and from the commercialization of climate commodities. When N rate applications are reduced, nitrous oxide emissions are reduced compared to a baseline rate that is not informed by PSNT.
Reduction of N inputs by using precision N management. (590)	Tailoring N supply to N demand based on zone management. Zones can be identified based on maps of yield, soil, and terrain analysis through a systematic and repeatable process.	Benefits accrued from reduced cost and from the commercialization of climate commodities.

Table 3. Cont'd

Practice name	Description	Expected benefit
Enhanced Efficiency N Fertilizers (EENF). (590)	When using N fertilizer, add a nitrification inhibitor, urease inhibitor, and/or slow or controlled-release N formulation (polymer coating). Emissions are reduced by limiting nitrification and denitrification.	Up to 50% nitrous oxide emission reduction, with strong dependence on the EENF or the combination of EENF used. EENF should be used when the crop N demand has been established and the N application rate adjusted to avoid excess N.
Early (or earlier) spring manure application. (590)	Apply manure in early spring to growing cover crops as opposed to terminated cover crops later in spring when temperatures are warmer.	Reduce N_2O emissions compared to applying manure to terminated cover crops later in the spring.
Optimization of N management through practices not accounted for in the options above.	Consideration of these practices requires empiric- or model-based evidence or monitoring that allows quantifying benefits. These include: + removal of cover crop biomass above 1000 lb/ac of green dry mass before tillage; + application of manure to growing crops as opposed to terminated cover crops later in spring (threshold growing degree days required); + frequent application of manure or N fertilizer to reduce average soil nitrate concentration (avoid nitrate bulges); + use of crops with biological nitrification inhibitor (BNI) potential; + use of a combination of practices not considered in this list, such us but not limited to short-corn that allows more frequent application of lower N fertilization rates.	Practice must document a reduction in emission of nitrous oxide compared with the baseline practice. To be eligible for funding, the practice must be associated to an NRCS practice code.