Aiming for Net Zero on Dairy Farms: Nutrition and Management Approaches

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Summary

Achieving Net Zero on dairy farms will require reducing the carbon **(C)** footprint of feed production, enteric and manure methane emissions from cattle, and reducing fossil fuel use in farm equipment and indirectly for electrical generation. Feed production, enteric methane, and manure methane contribute approximately 20, 25, and 25%, respectively, to the overall C footprint of dairy production (Thoma et al., 2012). Nutritionists can provide valuable assistance to dairy farms as they evaluate various strategies to achieve Net Zero and implementing approaches focused on cropping practices, cattle management, feeding programs and use of feed additives.

Greenhouse Gases – the Big 3

Methane **(CH_4)** along with carbon dioxide **(CO_2)** and nitrous oxides **(NO_x)** are the three biggest greenhouse gases **(GHG)**. Methane arises from natural and manmade sources, and methane is removed from the atmosphere by oxidation to CO_2 (major pathway) and by methanotrophs found in soil and aqueous environments (minor pathway). Anthropogenic methane is produced in fossil fuel use and distribution, by agriculture, and waste treatment. In developed countries like the USA, CO_2 emissions from fossil fuel use outweighs CH_4 emissions from all sources (Figure 1a). Although it's often stated that enteric methane is the largest source of anthropogenic methane, that's solely based on EPA point source classifications (EPA, 2019). In fact, fossil fuel production and distribution releases more CH4 than all animal agriculture does (Figure 1b).

Why is enteric methane from cattle at the forefront of climate change discussions again? The recent uptick in the focus on methane stems from the release of the 6th Assessment Report by the IPCC (United Nations International Panel on Climate Change, 2021), calling for massive and immediate cuts in GHG emissions. Because methane has a half-life in the atmosphere of only 10 years compared to 1000 years for CO_2, reductions in its emissions could lead to more rapid progress in reducing atmospheric GHG concentrations. However, this is only true if CO_2 emissions are held constant.

Dairy's C (Carbon) Footprint

GHG emissions comprise the C footprint of an industry, product, or service. For U.S. dairy, 70 to 75% of the C footprint of milk occurs before the farm gate, with enteric methane, manure methane, and NOx from N fertilizer use being the largest components (Figure 2; Thoma et al., 2012). Many papers have been published on currently available approaches and future needs in reducing enteric and manure methane

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(Gerber et al., 2013; Knapp et al., 2014; Kebreab and Feng, 2021; Place and Mitloehner, 2021). C footprints for foods are often expressed on an intensity basis as GHG/lb or kg product, with GHG on a CO_2-equivalent **(CO_2e)** basis that accounts for the differential greenhouse warming potential. As milk yield continues to increase through genetic selection and supporting cattle management, the C footprint of dairy declines on an intensity basis (Knapp et al., 2014; Capper and Cady, 2020 Place and Mitloehner, 2021). Over the past 80 years, the C footprint of U.S. dairy has decreased by 63% (Capper and Cady 2020). Similar improvements have been achieved in Europe, Israel, Australia, and other developed countries.

Net Zero for Agriculture and Dairy

The 2012 published C footprint for U.S. dairy (Thoma et al., 2012) does not include any offsets of GHG emissions for soil C fixation or reforestation, only emissions directly associated with production of milk and dairy products. In contrast, Net Zero is a balance sheet between GHG removal and emissions based on the whole farm ecosystem. Only agriculture and forestry can remove GHG naturally. While other industries can reduce emissions by switching to renewable fuels for transportation, power, and electrical generation, they cannot remove GHG from the atmosphere via natural mechanisms. Technologies are being developed for industrial carbon capture, where CO_2 is pumped deep into rock formations where it will be trapped for millennia or captured in chemical reactions. These carbon technologies require significant capital investments in infrastructure and energy to operate the systems and will only be viable with the extensive development and implementation of renewable energy systems. Also, they add costs to any industrial process, even when used to enhance extraction of tar sand and shale oil.

In agricultural systems, Net Zero is achieved when GHG removal exceeds emissions (Place and Mitloehner, 2021). Removal is achieved through fixing CO_2 in soil or forests. Reductions in CO_2 emissions in crop production can be achieved by reduced/no till practices and shifting annual crop production to perennial forages. NO_x emissions can be reduced by reduced N fertilizer use and incorporating manure into soil upon application. In the U.S., agricultural and forest land sequesters 12% of the nation's C emissions, while agriculture generates 10% of CO_2e emissions (Newton, 2021; EPA, 2019). In other words, U.S. forestry and agriculture are a net C sink! Individual farms are not likely to be Net Zero currently unless they have large tracts of woodland or forests.

At this time, there are no government regulations or formalized process for certifying Net Zero in the U.S. Companies have started up to provide third-party certifications using a variety of approaches to estimate carbon removal and GHG emissions in crop and animal agriculture. While verified carbon removal could earn producers carbon credits and potentially new revenue, selling the credits reduces the potential to achieve Net Zero on a farm or ranch and presents a conundrum in sustainability policy development.

Management Approaches and Technologies

The six areas that have the largest impact on a farm's C balance sheet are preventing soil erosion, increasing soil C sequestration, reducing synthetic N and fossil fuel use, capturing and utilizing manure CH4 in anaerobic digester, and improving herd feed efficiency by reducing maintenance energy costs (Table 1). Specific practices have the potential to be win-wins, i.e. reducing GHG emissions and reducing farm expenses.

Feeding and Nutrition Approaches

Feeding approaches in support of Net Zero focus on reducing enteric CH_4. Nutritional and cow management approaches allowing for full expression of the continued genetic improvement of dairy cows and reducing the "overhead" of non-productive animals (replacement heifers and dry cows) are two areas that have been very successful in reducing the C footprint of dairy over the past 80 years (Capper et al., 2009; Capper and Cady, 2019). These are also a win in terms of profitability. Likewise, calf and heifer nutrition practices with reduced mortality and lower average age at first calving of 22 to 24 months and improved lifetime production will reduce enteric CH_4 emissions/lb or kg milk. If production or herd size is increased, however, the C emissions associated with enteric CH_4 will increase due to increased feed consumption.

Feeding practices that enhance propionate production in the rumen vs. acetate and butyrate reduce enteric CH_4 emissions per cow, e.g. increased concentrate to forage. However, the benefits of these practices to Net Zero may be neutral, as concentrates may have a larger C footprint than perennial forages, especially corn grain and corn by-products due to emissions associated with N fertilization. Fat feeding also reduces enteric CH_4 by reducing the amount of fermentable carbohydrate and potentially decreasing dry matter intake (Knapp et al., 2014).

Available feed additives to reduce enteric CH_4 have short-term effects in terms of reducing enteric CH_4 as the rumen microbial system adapts to them in three to four weeks, and they add to feed costs (Table 2). These additives include monensin, live yeast and yeast cultures, saponins, condensed tannins, essential and algal oils (Agolin Ruminant™, Nuqo), etc. (Table 2; Gerber et al., 2013; Knapp et al., 2014; Kebreab and Feng, 2021). Improved feed efficiency is often, but not always, observed with these feed additives, providing a financial benefit. No research has investigated the effects of rotating feed additives to achieve longer term reductions in enteric CH4 in beef or dairy cattle. Four feed additives that have been tested in research but are not yet approved for use in the U.S. feed industry include nitrate, sulfate, seaweed, and 3-nitrooxypropanol (Bovaer™, DSM; Table 2). The first three have potentially toxic effects for cattle feeding. Seaweed compounds (although not algal oils) also have human health concerns regarding elevated milk iodine and bromoform levels. Lastly, feed additives that could reduce manure CH_4 on farms with anaerobic digesters are not desirable.

Every feed has a C footprint associated with its production (Adom et al., 2012). Current ration balancing software does not include this information, but it would be relatively simple to add it into feed libraries and formulate with a constraint on ration C footprint. As agronomic practices change, the library would need to be updated. Ration balancing software in current use do provide estimates of enteric and manure CH_4 along with N excretion, providing useful tools for the practicing nutritionist to estimate and monitor the GHG emissions associated with a farm's feeding program.

In conclusion, dairy nutritionists can bring reliable information and insights to farm decision making directed at achieving Net Zero goals. At the farm level, approaches that can be implemented include cropping practices aimed at reducing soil erosion and N fertilizer use, increasing soil C sequestration, capturing manure CH_4, and reducing energy use or switching to renewable energy sources in equipment and buildings. Continual improvement in cattle management and whole herd feed efficiency aid in reducing the impact of enteric CH_4 as part of the Net Zero approach. Feed additives may be a minor part of the overall approach.

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Table 1. Farming practices to enhance C sequestration and reduce GHG emissions (USDA NRCS, 2021).

Preventing soil erosion	Reduced tillage, no tillage, permanent buffer strips, cover crops, windbreaks
Increasing soil C sequestration	Reforestation, windbreaks, converting annual row crops to perennial forage crops, managed intensive grazing
Reducing synthetic N fertilizer use	Precision fertilizer, switching to legume forages, crop rotations to increase soil N
Reducing fossil fuel use (direct, indirect)	Reduced tillage, improving energy efficiency in buildings, using manure methane for fuel or electrical generation
Capturing manure CH_4	Anaerobic digester
Improved herd feed efficiency	Selecting for higher milk component yields and lifetime production, reducing age at first calving, reduced culling, not carrying excess replacement heifers.

Table 2. Feed additives currently available and under development for decreasing enteric methane emissions in cattle. Approval for use status is according to U.S. FDA and AACO feed regulations. Currently available feed additives do not have sustained effects in reducing enteric methane emissions.

Currently Available and Approved for Use	**Under Development and Not Approved for Use**
monensin	nitrate
saponins, e.g. *Yucca shidgera* extracts	sulfate
yeast and yeast culture	3-nitrooxypropanolol
condensed tannins	red seaweed, e.g. *Asparagopsis taxiformis*
essential oils	brown seaweed
algal oil	

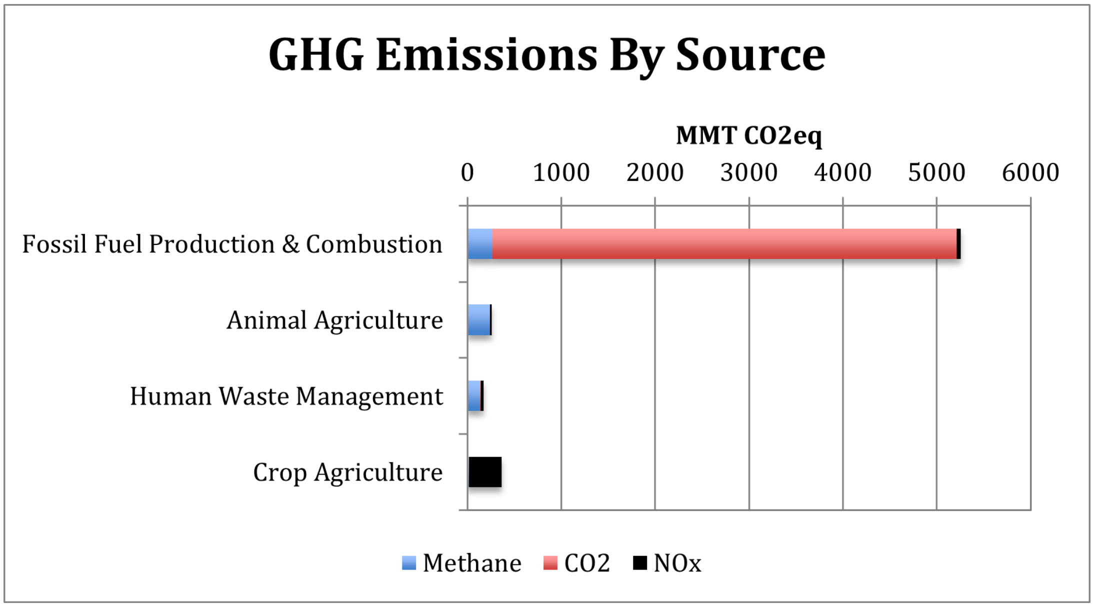

Figure 1a. U.S. Greenhouse gas emissions by source in million metric tonnes of carbon dioxide equivalents (MMT CO_2eq). Data from EPA (2019). CO_2 – carbon dioxide, NO_x – nitrous oxides.

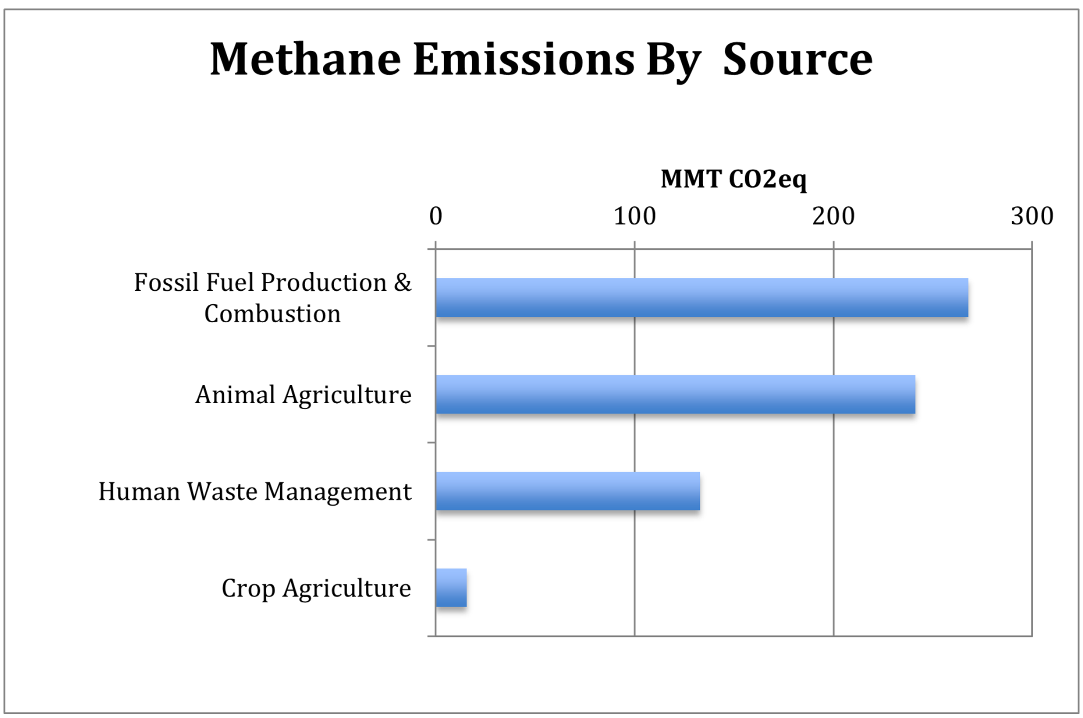

Figure 1b. U.S. methane emissions by source. Fossil fuels include coal, oil and natural gas. Human waste management includes landfills and municipal water treatment plants. Data from EPA (2019).

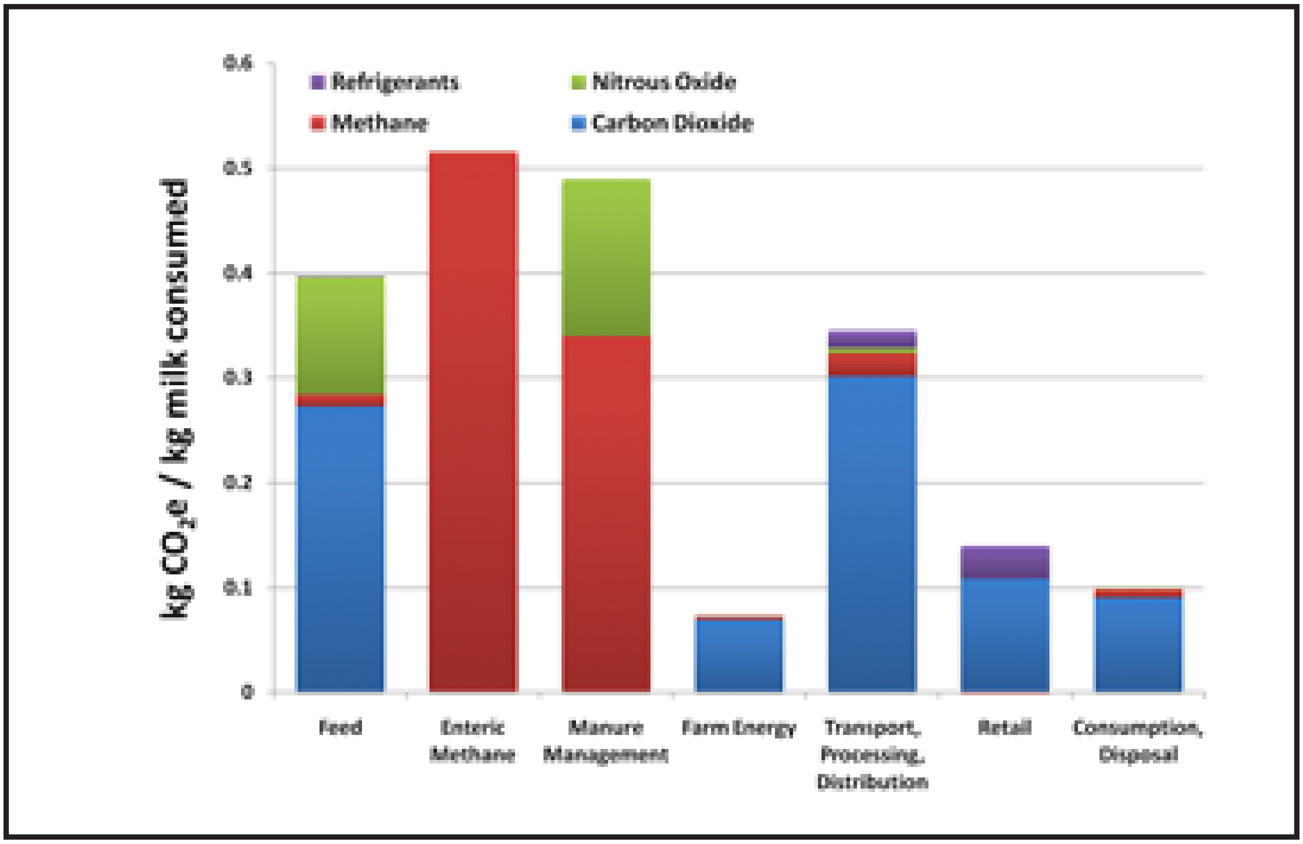

Figure 2. Carbon footprint of the U.S. fluid milk production (Thoma et al., 2012).