The veterinarian's role in reducing GHG emissions from beef and dairy production

Colin M. Beal, PhD

Chief Sustainability Officer, Select Sires, Inc.
Lander, WY 82520

Abstract

The beef and dairy industries make significant contributions to sustainability objectives by providing our society with nutritious food, supporting farmers' livelihoods, generating billions of dollars in economic activity, and contributing to healthy ecosystems. However, cattle production also generates negative environmental impacts, including greenhouse gas (GHG) emissions. Veterinarians have a unique opportunity to interface with beef and dairy farmers to assist with the implementation of products and practices that reduce GHG emissions, such that their clients can be more profitable and more sustainable. In general, the GHG intensity of beef and dairy production can be reduced by increasing output yields of beef and milk, while reducing inputs and maximizing efficiency. Some of the specific interventions include: early entry of feeder cattle to a feedlot, dry manure management, optimized inorganic nitrogen fertilizer use, increased fat in the ration, use of anti-methane feed additives and ionophores, sourcing low-carbon corn, selecting genetics for high feed efficiency, raising moderate/small mature beef cows and feed efficient dairy cows, improving pregnancy rate and reducing dystocia, conducting pregnancy checks, implementing artificial insemination, promoting herd health products and practices to reduce death loss, using growth-promoting implants, and utilizing SOP Lagoon®. As a trusted source of scientific information, veterinarians can be a conduit of information for producers and contribute to the ongoing effort to improve the resiliency of the beef and dairy industries.

Key words: GHG emissions, sustainability, veterinary medicine, consulting

Introduction

Sustainability has been defined as "the ability to meet the needs of the present without compromising the ability of future generations to meet their own needs," and generally spans social, economic, and environmental segments of our society.[1] Objectives of sustainable agriculture are to: satisfy human food needs; sustain economic viability; conserve natural resources; protect quality of life for farmers; and preserve the environment.[2] The beef and dairy industries make significant contributions to these sustainability objectives, as follows:

1. **Social benefits.** Roughly 84 million tons (77 million tonnes) of beef and 1,012 million tons (918 million tonnes) of milk were produced worldwide in 2021.[3] In the United States (U.S.) in 2021, beef production was nearly 14 million tons (13 million tonnes)[4] and milk production exceeded 113 million tons (103 million tonnes)[5], corresponding to an average annual production in the U.S. of roughly 85 lb (39 kg) of beef and 685 lb (311 kg) of milk per capita, respectively. Beef and dairy products provide several important nutrients (protein, iron, calcium, zinc, choline, selenium and vitamins A, B, and D) that contribute to healthy diets and provide a desirable eating experience for many consumers. Leather, tallow, organs, bones and manure fertilizer are also valuable products for our society derived from beef and dairy cattle. In addition, these industries support the livelihoods of more than 700,000 U.S. beef farms (with more than 80% being family-operated) and 50,000 U.S. dairy farms.[6]
2. **Economic benefits.** Live beef cattle sales generate over $80 billion and retail beef sales generate over $188 billion of economic activity in the U.S. annually.[7] Similarly, cash receipts for whole milk sales exceeds $40 billion,[8] which feed into a variety of added-value consumer retail products. These economic impacts help to support many family-owned small businesses and rural communities, while providing affordable food for consumers.
3. **Environmental benefits.** Cattle grazing systems can contribute to maintaining healthy grasslands, improving soil quality, enabling productive lands that continue to support wildlife, and increasing soil carbon storage.[9–11] Cattle also enable upcycling of inedible forage into human foods[12] and the ability to utilize non-arable lands and low-quality water[13] sources for food production.

Despite the numerous benefits of beef and dairy production, there are also significant negative environmental impacts associated with beef and dairy production, including greenhouse gas (GHG) emissions, ammonia emissions, direct and indirect land use for grazing livestock and producing feed, direct and indirect water use for drinking water and producing feed, damage to soil and riparian areas resulting from poor management, and interference with wildlife habitats.[10,14–21] In particular, cattle have received widespread attention associated with their GHG emissions. Beef and dairy cattle generate approximately 5% and 4% of global GHG emissions, respectively.[18,22] These emissions are generated from a variety of sources within the beef production lifecycle, including enteric methane production, methane and nitrous oxide from manure, direct on-farm emissions (such as diesel combustion in tractors), and embedded upstream emissions generated during the production of feeds, seeds, fertilizers, etc. used in beef and dairy production.[14,16,18,23–26] Meanwhile, global temperatures and atmospheric GHG concentrations continue to increase,[27,28] raising broader concerns about the negative impact of future climate changes on global society. As a result, there are numerous sustainability initiatives aimed at reducing GHG emissions from the beef and dairy industries, including the following initiatives from the 3 largest beef packers in the U.S. and the 3 largest milk processors in the U.S.:

- "Tyson Foods Targets 2050 to Achieve Net Zero Greenhouse Gas Emissions"[29]
- "JBS is committing to be Net Zero by 2040"[30]
- "Cargill expands climate change commitments. Company makes science-based commitment to reduce supply chain emissions by 30% by 2030."[31]

- “Climate change is a profound, systemic challenge – not in the future, but right here, right now. Danone is meeting this challenge head on by aligning to the Science-Based Targets initiative and committing to net-zero emissions by 2050.”[32]
- “Kraft Heinz committed to achieve net-zero greenhouse gas emissions across its operational footprint (Scope 1 and 2) and global supply chain (Scope 3) by 2050, with a near-term goal of halving emissions by 2030.”[33]
- “As leaders in sustainability, [Dairy Farmers of America are] working toward a net zero or net negative carbon footprint for our Cooperative and U.S. dairy.”[34]

Although there have been many goals set by government and corporate entities for reducing GHG emissions from cattle, most beef and dairy farmers are not incentivized to reduce the GHG emissions from their herd and do not have the tools, knowledge, or guidance that will be required to make the reductions. Low Carbon Technologies, LLC (LCT), a division of Select Sires, Inc., is focused on using science-based programs to add-value to beef and dairy products that are produced with reduced GHG emissions and provide more confidence for consumers who purchase these products about the environmental impacts of their food. Meanwhile, as a trusted source for scientific information and herd management, veterinarians have a unique opportunity to interface between LCT and cattle farmers. This manuscript describes the management practices, commercial products, and cattle performance metrics associated with LCT’s programs and the suggests roles that veterinarians can fill to help communicate these topics to their clients (i.e., cattle farmers), such that their clients can be more profitable and more sustainable.

Low carbon technologies overview

LCT is a newly formed company within Select Sires that, in 2022, acquired Low Carbon Beef, LLC, which was a company devoted to differentiating and certifying beef cattle that are produced with reduced GHG emissions. The goals of LCT are to commercialize the existing beef programs from Low Carbon Beef, extend operations to include dairy applications, broaden the scope of work to sustainability criteria beyond GHG emissions, and to eventually expand the programs to include additional livestock species and agricultural commodities. As a farmer-owned cooperative, Select Sires and LCT are motivated by the desire to improve the resiliency of the beef and dairy industries, help farmers engage in the sustainability space, and contribute to farmers’ abilities to sustain their businesses and livelihoods. In addition, LCT is focused on contributing to the sustainability goals of meat packers, milk processors, and retailers to quantify and verify emissions reductions in their supply chains to achieve their sustainability initiatives and add-value to products with reduced emissions for wholesale and/or resale. Consumer surveys conducted by LCT found that over 70% of beef consumers stated that they would be willing to pay a premium for sustainability. As such, providing this type of product differentiation also offers opportunities for beef and dairy producers and retailers to improve their brand image with consumers who are concerned about sustainable food production.

Low carbon technologies’ methodology

Life cycle assessment

In recent years, standardized life cycle assessment (LCA) protocols have been developed for quantifying the environmental performance of a variety of beef production systems.[14,16–18,35,36] Most of these studies provide performance results at the global, national, or aggregate producer level, without enabling the resolution to evaluate (and certify) individual animal performance. As a result, these studies have had limited practical market application and consumers have been unable to differentiate beef produced with low GHG emissions from beef produced through conventional means with higher emissions. By incorporating producer-specific management practices and cattle performance into the LCA, LCT provides producers and consumers the ability to quantify and certify emissions for individual animals.

LCT uses a comprehensive and proprietary LCA model to quantify the GHG emissions from candidate cattle, as represented in Figure 1. The LCA model is based on ISO standards (e.g., 14040 and 14044)[35] and IPCC guidelines[17]. The LCA model incorporates production data from a variety of sources (e.g., USDA reports, peer-reviewed literature, and breed association data) in order to provide an analytical characterization of beef production emissions. The model is regularly updated to follow revised guidelines and include the most up-to-date research findings and reports.

The baseline production scenario represents typical and current industry practice and serves as a reference point for comparing the GHG emissions among different scenarios. The baseline scenario is based on the Backgrounding (BG) pathway described below. LCT uses an emissions scoring table (described below) to determine the certification status of candidate cattle and the emissions scores are determined using the LCA model. For example, if a management practice reduces life cycle GHG emissions by 5%, candidate cattle would receive a score of 5 if they were raised under that practice. Scores can be positive (for beneficial operations with reduced emissions) or negative (for unfavorable operations with increased emissions). The primary objective of this model is to “consistently compare performance among different animals in a variety of production systems using the same model.”

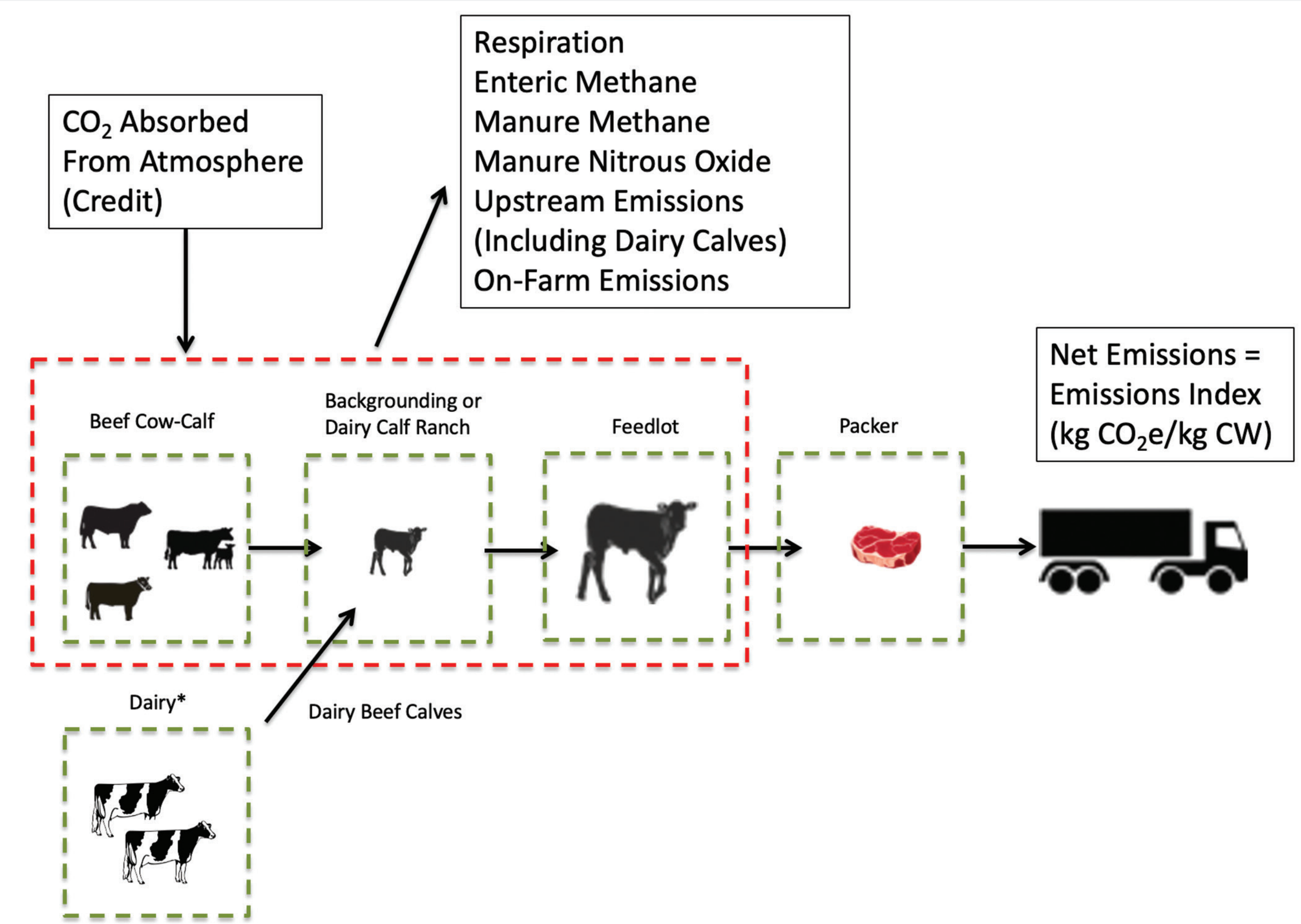
A process flow diagram that depicts the control volume and the sources and sinks of emissions is provided in Figure 1. The control volume applied to this analysis can be conceptualized as the aggregate physical space (several rectangular prisms) contained within production system perimeters (e.g., exterior fences or feedlot perimeter), extending above the ground to include plants, animals, and the atmosphere. A complete carbon balance is included in the LCA and biogenic carbon uptake into feeds is tracked through the control volume as part of the LCA. As the purpose of these production systems is to produce beef for human consumption, the functional unit selected for the LCA is 1 kg of carcass weight and economic allocation methods are used for GHG accounting.

Certification programs

LCT currently offers 2 certification programs:

1. **USDA Process Verified Program (PVP) –** Certifies fed cattle within 60 days of slaughter. Candidate cattle qualify if they demonstrate a 10% reduction in GHG emissions below the industry baseline and thereby receive an emissions score > 10. Protocols apply to raising cattle within one of 4 production pathways: 1) weaned calves are backgrounded on forage for > 3 months (Backgrounding, BG); 2) weaned calves enter a feedlot < 3 months after weaning (Direct-Entry-to-Feedlot, FL); 3) cattle are grass-fed consistent with the USDA’s definition (Grass-Fed, GF); and 4) candidate cattle are dairy-beef calves (Dairy-Beef, DB). Data is collected for

Figure 1: LCA system boundaries for the 4 production pathways included in the LCT programs.



the candidate cattle from birth to slaughter for the criteria described below. (Note: LCT is currently in the process of revising the USDA PVP and the information presented in this manuscript includes the anticipated updates.)

2. **LCB Enrolled –** Certifies feeder calves at weaning or after backgrounding based on the same criteria as the USDA PVP, but limited to only the cow-calf and backgrounding (if applicable) segment(s). Candidate cattle qualify if they receive an emissions score > 7.5. Protocols apply to the same production pathways as the USDA PVP, excepting the DB pathway, and this program is administered as a partnership with IMI Global.

LCT is also working to develop future certification programs for dairy products using a dairy-only LCA model that will quantify and certify milk production GHG emissions (kg CO_2e/kg energy-corrected milk).

Program criteria and implementation

Scoring is determined from data that LCT collects from cattle producers to quantify GHG emissions. For LCB Enrolled, LCT gathers data from cow-calf producers and backgrounders, while for the USDA PVP, LCT also gathers data from the dairy for DB calves and from the finishing segment (for all calves) to evaluate the entire lifecycle. LCT serves as the verification body, conducting the necessary record keeping, annual on-site verifications, and compliance to ensure the product meets the requirements of each program. LCT certifies cattle, not raising locations, and works with producers to collect the necessary data to complete each certification.

The first thing LCT needs to begin a certification is identifying information for the candidate cattle, including a head count and a specific group identification, such as a lot number, pen number, EID numbers, or pasture identifier. Once LCT has the candidate cattle identified, they use a standard questionnaire to gather information about management practices and herd performance. LCT can email the questionnaire to producers or conduct a phone interview to collect the information. For each certification, LCT fills out an Emissions Score Worksheet for the candidate cattle, assigning scores for each of the criteria listed in Table 1, below. The scores are determined from the proprietary Scoring Table, which is based directly on the life cycle assessment described above. Scores can be positive or negative and Table 1 provides recommendations for the preferred or beneficial conditions for each criterion in the Scoring Table. LCT uses the same scoring table for LCB Enrolled and the USDA PVP, but for LCB Enrolled, LCT only evaluates the segments that apply for the candidate cattle (e.g., weaned calves being sold off the ranch of birth will not have scores for any backgrounding or finishing criteria).

There are 4 production pathway options (pending final approval of the revised PVP): Backgrounding (BG), Direct-Entry-to-Feedlot (FL), Grass-Fed (GF) and Dairy-Beef (DB). The first step in determining the Emissions Score is to determine which pathway applies for candidate cattle, as defined below. If candidate cattle do not meet the specifications for any of these pathways, they are disqualified from the programs. Each pathway receives a pathway score in addition to the other 19 criteria in the Scoring Table. The pathway score represents the difference in emissions between the pathways when each pathway is operated with baseline conditions, where the BG pathway is considered the industry baseline. In general, DB calves receive the highest pathway score, primarily reflecting reduced emissions resulting from the co-production of milk, cull cows and dairy-beef calves in a dairy operation as compared to conventional beef systems where dams are solely devoted to producing beef calves. FL calves receive a positive score compared to the BG baseline associated with higher feed conversion rates associated with a longer period in the feedlot.

Similarly, GF cattle receive a significantly negative pathway score due to lower feed efficiency on forage diets leading to longer lifespans and more emissions per pound of beef yield. The pathways are defined as follows:

- **Backgrounding Pathway (BG):** The BG pathway represents a production process in which cattle are born and raised in a cow-calf operation until weaning, raised on forage after weaning, and then finished in a feedlot. To qualify for the BG pathway, candidate cattle can be raised with their mothers for up to 10 months, must spend at least 3 months in a backgrounding location between weaning and entry to a feedlot, and spend at least 2 months in a feedlot.
- **Direct-Entry-to-Feedlot (FL):** The FL pathway represents a production process in which cattle are born and raised in a cow-calf operation until weaning and then raised in a feedlot from weaning to slaughter. To qualify for the FL pathway, candidate cattle can be raised with their mothers for up to 10 months, must spend less than 3 months in a backgrounding location between weaning and entry to a feedlot, and spend at least 2 months in a feedlot.
- **Grass-Fed (GF):** The GF pathway represents a production process in which cattle are born and raised in a cow-calf operation until weaning, raised on forage after weaning, and then finished on forage until slaughter. Our classification for GF is consistent with the definition provided by the USDA FSIS, which is: "'Grass Fed' claims may only be applied to meat and meat product labels derived from cattle that were only (100%) fed grass (forage) after being weaned from their mother's milk. The diet must be derived solely from forage, and animals cannot be fed grain or grain by-products and must have continuous access to pasture during the growing season until slaughter. This means 100% grass-fed animals are never confined to a feedlot."
- **Dairy-Beef (DB):** The DB pathway represents a production process in which calves born from dairy cows are raised in a dairy calf ranch until weaning and then raised in a feedlot from weaning to slaughter. To qualify for the DB pathway, candidate cattle must be separated from their (dairy cow) mothers by 7 days of age, weaned off milk by 5 months of age, and spend at least 2 months in a feedlot. Candidate cattle must be sourced from a dairy with one of the following manure management systems: deep bedding, solid storage, dry lot, daily spread, composting, pasture/range/paddock, anaerobic digestor (high-quality), liquid/slurry treated with SOP Lagoon®, anaerobic lagoon treated with SOP Lagoon®, deep pit treated with SOP Lagoon® (note: untreated anaerobic lagoons, liquid/slurry, or deep pits disqualify the candidate cattle). The source dairy feed efficiency also must be < 1.0 kg DMI per kg whole milk production.

Low Carbon Technologies' USDA Climate Smart pilot program

In 2022, the USDA committed $3.1 billion to fund 141 pilot projects within the Partnerships for Climate-Smart Commodities program.[41] LCT was selected for a $10M, 5-year pilot program that was launched in June of 2023. The goal of this pilot project is to implement climate-smart methods from conception to consumption over a 5-year period to produce ~8,000 head of cattle that:

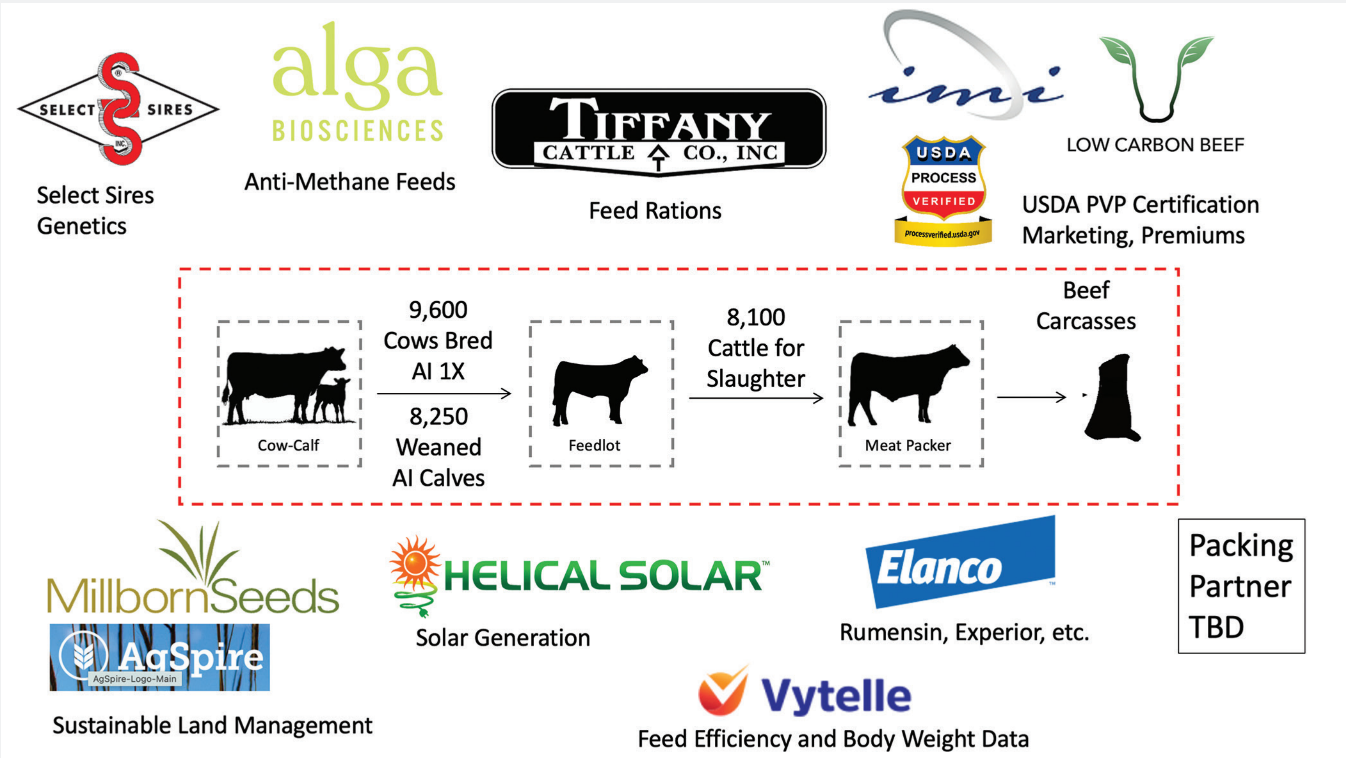
1. Demonstrate at least a 50% reduction in GHG emissions over the current U.S. baseline.
2. Produce beef that is sold in retail markets with Low Carbon Beef's USDA Process Verified Program (PVP) certification to generate substantial market premiums and voluntary carbon credit revenue for cattle producers and retail partners.

This project will pilot a fully integrated approach for the commercial cattle industry with measured GHG outcomes for specifically identifiable animals based on the best available science. To achieve these goals, this consortium brings together industry leaders shown in Figure 2 in the areas of genetics (Select Sires), land management (AgSpire and Millborn Seeds), anti-methane feed additives (Alga Biosciences), solar power (Helical Solar), and herd health/nutrition (Elanco). The team includes industry leaders in feed intake and body weight measurements (Vytelle), as well as experts in monitoring-recording-and-verification for consumer marketing of existing branded beef products (LCT and Where Food Comes From). Cattle producers in the pilot program will span a range of small, underserved and large operations from many states within the team's existing customer base and will integrate with our feedyard partner (Tiffany Cattle Co.) to demonstrate end-to-end climate-smart beef production.

To enable value-added marketing, the consortium will use LCT's proprietary certification process, as described above. By combining the most effective products and practices from the industry partners on this team, the program will produce and market commodity beef with > 50% reductions in GHG emissions, and demonstrate some net-negative-emissions production scenarios. Funding from this program will be used for producer incentives to enable climate-smart methods to be deployed ranging from cow-calf producers to consumers. The cattle produced in the project will be monitored within the USDA PVP protocols and marketed at commodity scale to generate premiums for ranchers, feedyards, meat packers and retailers using existing industry practices for efficient financial transactions. Environmental co-benefits from this program will include improving soil quality, increasing soil water retention, reducing nitrogen runoff, increasing grass stocks for wildlife habitat, and reducing pressure on crop lands used to grow cattle feed by increasing feed efficiency and thus reducing feed/grain requirements.

LCT began accepting applications in September of 2023 from cattle producers to participate and receive substantial incentives as part of the pilot program. Interested producers should email Sarah Quallen at **squallen@selectsires.com**. Cow-calf producers with at least 50 cows can apply, including those who sell weaned calves or if they retain ownership through finishing. Benefits for producers enrolled in the program will include receiving the following products and services:

Figure 2: Low Carbon Technologies' Climate-Smart Commodities pilot program targets the production of roughly 8,000 head of cattle over a 5-year period with at least a 50% reduction in GHG emissions.



- Select Sires high performance genetics and AI breeding services (~$35/head/year value)
- High-performance natural service bulls (~$5,000/ each)
- Assistance in developing a nutrient management plan and grazing management plan at no cost
- Producer payments for cover crops, forage, and/or range plantings (up to $100/ac)
- Herd health and nutritional products at no cost (e.g., Compudose® and Rumensin®)
- LCB Enrolled certification for weaned calves (~$350/ operation value)
- Access to added-value premiums above market price (~$145/retained-ownership fed cattle or $45/weaned calf)
- Vytelle in-pen weighing systems and data collection at no cost (select producers only)
- Participation and networking in pilot program producer meetings

Requirements for participation include:

- Breed cattle with high-performance genetics
- Implement nutrient management, grazing management, and herd health plans
- Adopt at least one climate-smart planting (cover crop, forage, or range)
- Collect, maintain, and submit the necessary data and records for certifications
- Apply individual animal IDs (i.e., USDA RFID tags)
- Weigh 10% of the mature cow herd each year
- Maintain animal head count records for cows and calves
- Register with local FSA

Preference in selecting producers will be given for:

- Retained ownership producers
- Currently or can conduct soil testing to quantify soil carbon (organic matter test)
- Currently or can feed anti-methane feed additives
- Have reliable body weight scales on site (e.g., on their chute)
- Fit the description for diversity or underserved operations (such as small, beginner, veteran, or minority)
- Have existing relationships with the consortium team members
- Submitted a letter of interest for our proposal in May 2022

Conclusions: A veterinarian's role

As a trusted source of scientific information, veterinarians provide valuable guidance to beef and dairy producers, particularly for new products and innovative programs. Veterinarians can also fulfill this role regarding the reduction in GHG emissions from the beef and dairy industries to contribute to their clients' profitability and sustainability in the following ways:

1. Research and communicate financial opportunities in the carbon space to producers, including LCT's certification programs and emerging carbon credit markets.
2. Introduce LCT's USDA Climate Smart pilot program. Veterinarians can email Sarah Quallen at **squallen@selectsires.com** for more information and a copy of the producer application.
3. Share a flyer with producers describing LCB Enrolled and LCT's USDA PVP. Veterinarians can email Sarah Quallen at **squallen@selectsires.com** for more information and a copy of the flyer.

Table 1: The LCA calculates the amount of each emissions flux illustrated in Figure 1 and candidate cattle are assigned an Emissions Score, which is the aggregate score from the following 20 criteria (these criteria are pending final approval from the USDA PVP review).

Criteria	Notes
1. Production pathway score	DB calves receive the highest pathway score, followed by FL calves, BG calves (+0), and GF calves, which receive a significantly negative pathway score.
2. Cow-calf manure management	This criterion is not applicable at this time.
3. Backgrounding manure management	This criterion is not applicable at this time.
4. Feedlot/finishing manure management	Dry manure management systems are preferable – avoid anaerobic lagoons, deep pits, or liquid/slurry. Note: a runoff pond at a dry-lot feedlot is not considered a lagoon for this criterion.
5. Cow-calf inorganic nitrogen fertilizer	Higher scores are awarded to operations that avoid or reduce inorganic nitrogen fertilizer applied to grazing pasture or forage production fields (e.g., hay fields).
6. Backgrounding inorganic nitrogen fertilizer	Same as item 5.
7. Grass-Finishing inorganic nitrogen fertilizer	Same as item 5.
8. Fat in cow-calf diet	Increased fat content reduces enteric methane and positive scores can be received for fat content > 2.5% of dry matter intake.
9. Fat in backgrounding diet	Same as item 8.
10. Fat in feedlot/finishing diet	Same as item 8.
11. Cow-calf anti-methane feed additives	Anti-methane feed additives are expected to become commercially available soon and have been shown effective at significantly reducing the amount of enteric methane per pound of dry matter intake generated by the rumen. Side effects and long-term impacts are to be determined. Some examples include: Bovaer from DSM/Elanco[37] and products from Alga[38], Symbrosia[39], Mootral[40] and others (see Appendix Figure A3).
12. Backgrounding anti-methane feed additives	Same as item 11.
13. Feedlot/finishing anti-methane feed additives	Same as item 11.
14. Ionophores in cow-calf diet	Ionophores such as Rumensin® can improve feed efficiency and reduce enteric methane emissions per pound of dry matter intake. The impact of ionophores on enteric methane is generally less than anti-methane feed additives (criteria 11-13), but still significant to assign positive scores.
15. Ionophores in backgrounding diet	Same as item 14.
16. Ionophores in finishing diet	Same as item 14.
17. GHG impact (carbon intensity) of corn and distillers grains at the feedlot (only)	Upstream GHG emissions from producing corn for feed contributes to the overall GHG emissions for beef production. As such, sourcing corn and distillers grains from production system with low emissions (i.e., low carbon-intensity [CI]) results in positive scores.
18. Age-to-slaughter-weight score	Cattle with high feed efficiency (lb of gain per lbs of dry matter intake) reach a higher slaughter weight (and thus higher carcass weight and beef yield) at a younger age and are assigned higher scores.
19. Mature cow weight	There are more emissions from mature cows in a conventional beef production system than from the slaughter calves (the mature cows are larger, consume mostly forage rations, and generate emissions year-round). Mature cow weight is used as a proxy for dry matter intake, from which GHG emissions are calculated. As such, smaller mature cows receive higher scores.
20. Harvest ratio	Death loss reduces the amount of beef produced from a production system, which therefore increases the emissions intensity (kg CO_2e/kg carcass weight produced). As such, lower death loss rates receive higher scores.

4. Promote practices described in Table 1 and explain the rationale for each intervention, such as the preference for:
   - Early entry to a feedlot
   - Dry manure management
   - Optimized inorganic nitrogen fertilizer use
   - Fat content in the ration > 2.5% of dry matter
   - Use of anti-methane additives
   - Use of ionophores
   - Sourcing low-CI-scored corn and distillers' grains
   - Use genetics to produce feed efficient calves
   - Select genetics to produce or procure moderate/small mature cows that can produce calves with high growth rates and good feed efficiency
   - Improve pregnancy rate and reduce dystocia
   - Conduct pregnancy checks to avoid carrying open cows that generate emissions without producing beef
   - Implement artificial insemination to enable enhanced genetic selection and increase pregnancy rates
     - Genetic selection can focus on:
       - Terminal traits: Calving ease to reduce death loss (CED), high growth rate (WW, YW, CW), high feed efficiency (RADG)
       - Maternal traits: Calving ease to reduce death loss (CED), pregnancy rate (HP), small/moderate mature cow size (MW)
   - Promote herd health products and practices to reduce morbidity and mortality, including high quality feed, water and shelter, along with vaccinations and other health products
   - Promote SOP Lagoon®[42] for wet manure management, such as open lagoons or deep pits
   - Promote implants and other management practices to improve feed efficiency[24]

Sustainability will be a critical component in the beef and dairy industries for the foreseeable future. As the percentage of the U.S. population that works in agriculture continues to shrink, it is important for both industries to maintain credibility with consumers and provide affordable products. Veterinarians can contribute to these efforts by supporting their clients' sustainability initiatives and helping them add value to the commodities that they produce.

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Figure A1: Global greenhouse gas emissions in 2019. Source: World Resource Institute[22]

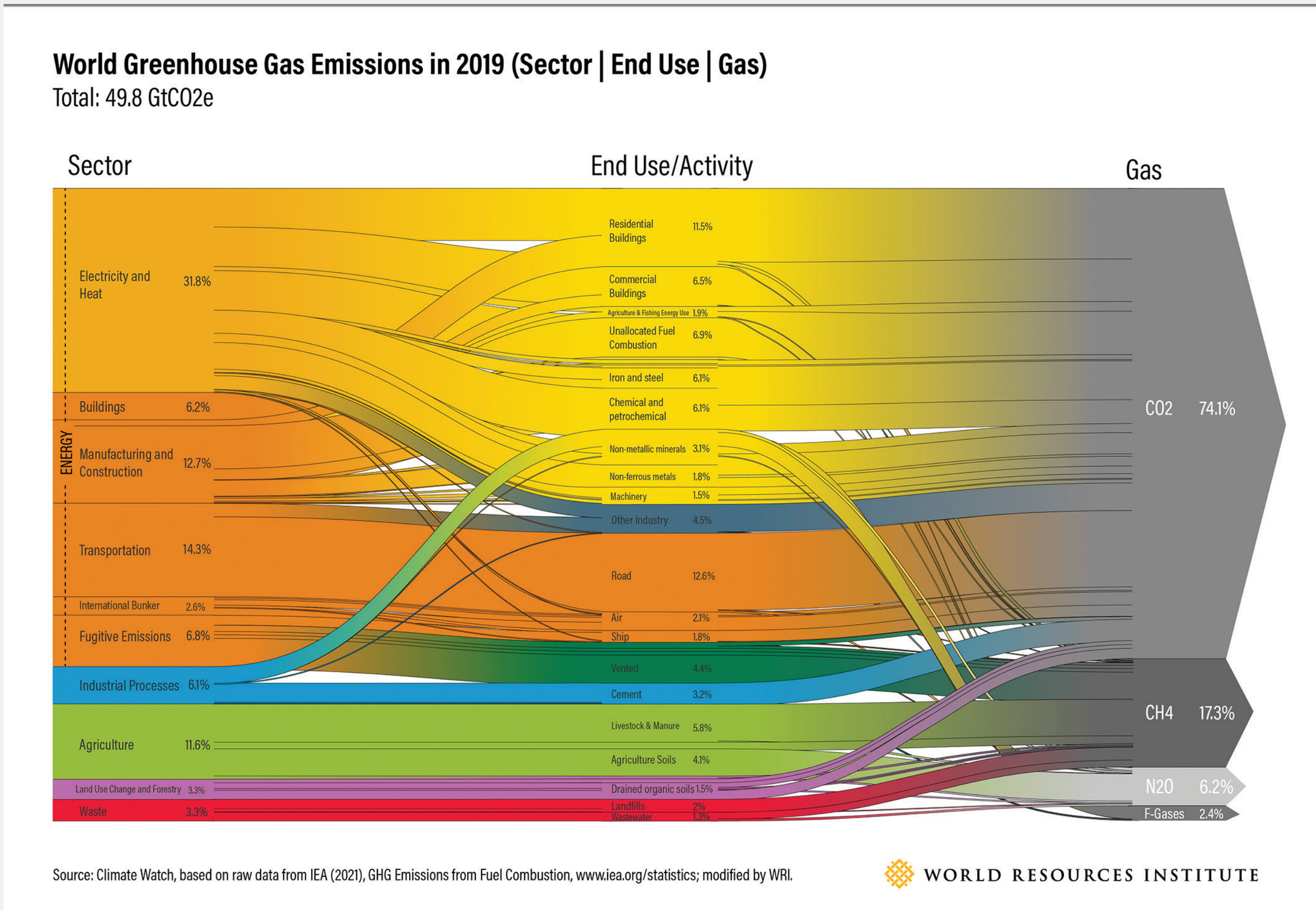

Figure A2: Global greenhouse gas missions from livestock. Source: Food and Agriculture Organization (FAO) of the United Nations, 2013[18]

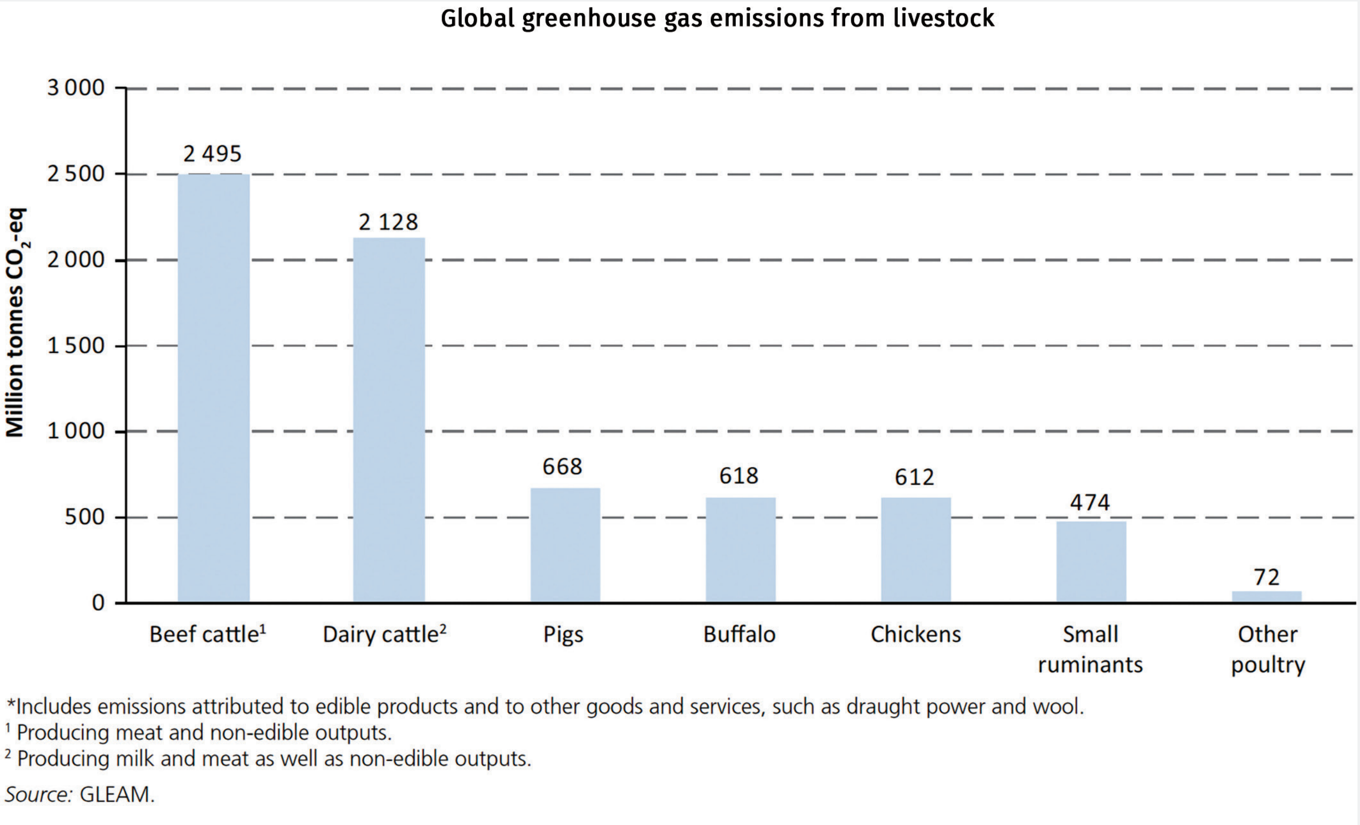

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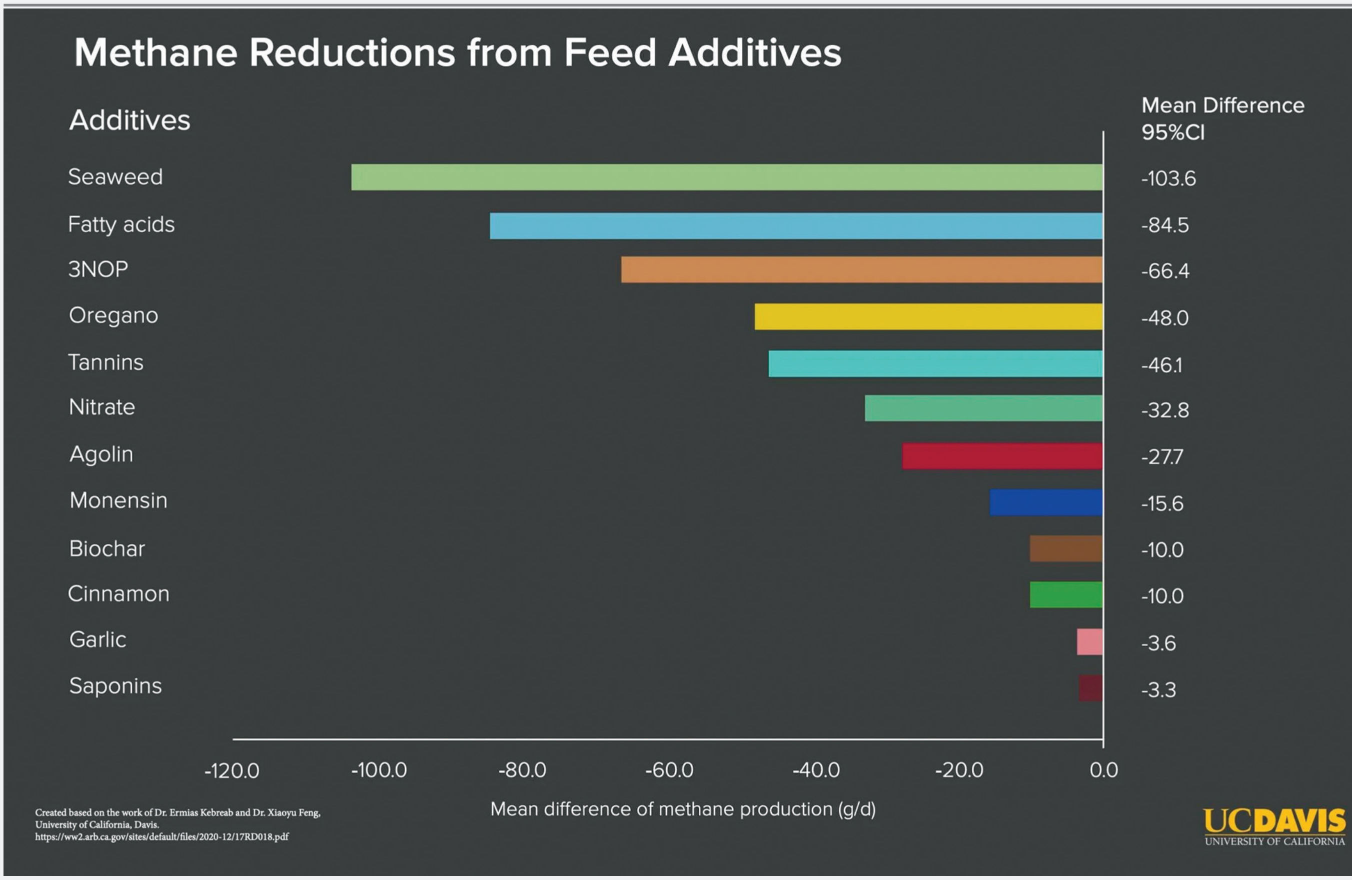
Figure A3: Enteric methane reductions from a variety of feed additives. Source: Darigold, citing UC Davis[43]



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