

## Environment, climate change, and ag sustainability

*Frank Mitloehner, PhD  
Director, CLEAR Center  
Professor and Air Quality CE Specialist  
Department of Animal Science  
University of California, Davis*

### INTRODUCTION

Climate change is a global issue that requires comprehensive and far-reaching solutions across all economic and demographic jurisdictions. The Paris Climate Agreement, adopted in 2015, sets out a global framework to address harmful climate impacts by limiting additional global warming to well below 2 degrees Celsius (°C) (1.5 °C goal). The accord recognizes regional differences and the need for specific actions across all jurisdictions, including developed economies providing leadership and assistance to developing nations in their climate mitigation efforts.

California continues to lead the United States and world in implementing measures to achieve emissions reductions of greenhouse gases (GHGs) that advance climate change. Toward this end, California has established ambitious goals for reducing GHG emissions (Senate Bill 32) by 40 percent by 2030 and 80 percent by 2050. Senate Bill 1383 (2016) also established specific goals for reducing short-lived climate pollutants (SLCPs), such as methane, by 40 percent from 2013 levels. Ultimately, California is working toward a goal of “net-zero” carbon emissions by 2045 (Executive Order B-55-18).

The U.S. dairy industry recently announced efforts to address climate change, boldly aiming for carbon neutral or better (net zero climate impact) by 2050 (Innovation Center for U.S. Dairy, 2020). As part of these important efforts, California’s dairy farms are leading change and making significant progress in reducing the amount of GHG emissions released into the environment. Producing a glass of milk from a California dairy cow generates 45 percent less GHG emissions today than it did 50 years ago. This finding, recently published in the Journal of Dairy Science, comes from a life-cycle assessment of California dairy farms in 1964 and 2014, conducted by researchers at the University of California, Davis (Naranjo et al., 2020). Significant advancements in farming efficiency, feed crop yields, veterinary care, sustainable feed practices, and animal nutrition have helped reduce the environmental footprint of individual cows. Building on these gains, more can be done to lower the climate footprint of milk production in the coming decade.

California’s dairy farmers are working closely with the California Department of Food and Agriculture (CDFA) and the California Air Resources Board (CARB) to further reduce dairy methane emissions. As the efforts continue, it is also important to improve our understanding

of how methane and other GHGs contribute to climate impacts, as we seek to limit warming. Leading climate scientists are now recognizing that moderately reducing methane emissions can quickly stabilize the climate pollutant's powerful impact, and further reductions can actually offset the far more damaging impacts of carbon dioxide (CO<sub>2</sub>), which accumulate in the atmosphere for hundreds of years.

### **California's Greenhouse Gas Emissions**

California, the fifth largest economy in the world, is responsible for about 1 percent of all global GHG emissions. More than 80 percent of California's emissions come from the transportation (41 percent), industrial (23 percent) and electrical (16 percent) sectors. Even though California is the United States' largest agricultural producer—producing fruits, vegetables, nuts, livestock, and other commodities for much of the U.S. and world—the sector's GHG contribution is only 8 percent of the state's total. California's largest-in-the-nation dairy sector accounts for about half of the agricultural share, or 4 percent of the state's total GHG emissions. The U.S. dairy sector accounts for 2 percent of the nation's total GHG emissions.

While CO<sub>2</sub> is the primary GHG driving climate warming, methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O), and refrigerants are also important GHGs in California. According to CARB, carbon dioxide accounts for about 83 percent of California's GHG inventory. In comparison, methane accounts for 9 percent, and N<sub>2</sub>O accounts for about 3 percent. In addition to knowing how much of each gas is being emitted, understanding how each gas causes actual warming is most critical to fully understanding and addressing climate change. Recent work by leading climate scientists at the Oxford Martin School and Environmental Change Institute at Oxford University has shed light on important differences among these GHGs and their impact on climate change (Lynch, 2019).

Methane emissions are generated by a number of processes, both those resulting from human related activity (anthropogenic) and natural (biogenic). Fossil-fuel methane (more commonly known as "natural gas") results from the process of extracting coal or oil, or from leakage during the extraction, storage, or distribution of natural gas for homes and businesses. Fossil methane is largely converted to CO<sub>2</sub> when we burn natural gas in our homes, factories, buildings, and other businesses.

Biogenic methane emissions are created by wetlands, rice cultivation, and ruminant livestock, as well as the waste sector, when microbes digest organic matter in our landfills and sewage treatment plants. Animal agriculture activity (all livestock) in California represents the largest source of biogenic methane emissions, accounting for roughly 55 percent of all human-related methane emissions in the state. California is the largest dairy state, producing roughly 18.5 percent of the nation's milk (USDA, 2019). The dairy livestock sector accounts for about 45 percent of all methane emitted in the state (CARB, 2015), primarily from two sources. Roughly half (55 percent) of dairy methane emissions come from manure management (storage, handling, and utilization), and the remaining 45 percent comes from enteric emissions.

In ruminant animals, methane is produced during manure decomposition as well as during enteric fermentation, where microbes decompose and ferment plant materials in the first compartment of their stomach, known as the rumen. This methane is expelled by the animal through belching.

### **Fossil Methane vs. Biogenic Methane**

Fossil methane impacts the climate differently than biogenic methane. Fossil methane, such as natural gas, is carbon that has been locked up in the ground for millions of years and is extracted and combusted in homes and businesses. The burning of fossil methane directly transfers carbon that was stored in the ground (geologic carbon) into the atmosphere as CO<sub>2</sub>. That carbon continues to accumulate and persist in the environment, contributing to climate change for hundreds of years. Bottom line: Fossil methane increases the total amount of carbon in the atmosphere, which drives warming.

Biogenic methane from cows is part of a natural carbon cycle, where after about 12 years it is removed from the atmosphere. As part of photosynthesis, plants capture CO<sub>2</sub> from the atmosphere, absorbing the carbon and releasing oxygen. That carbon is converted into carbohydrates in the plant, which are then consumed by the cows, digested, and released from the cows as methane (CH<sub>4</sub>). After about 12 years in the atmosphere, that methane is oxidized and converted into CO<sub>2</sub>. These carbon molecules are the same molecules that were consumed by cows in the form of plants. As part of the biogenic carbon cycle, the carbon originally utilized by the plant is returned to the atmosphere, contributing no net gain of CO<sub>2</sub>.

### **Global Warming Potential of California's Primary Greenhouse Gases**

Each GHG captures and retains heat at a unique rate, known as its global warming potential or GWP (as shown in Table 1 as GWP 100). For example, CH<sub>4</sub> has 28 times the warming potential of CO<sub>2</sub> over a 100-year period. Understanding how emissions impact global climate; however, requires consideration of not just the potency, but also how long each type of GHG will last in the atmosphere (atmospheric lifetime).

This is particularly important for methane, as it is a SLCP, with emissions breaking down after about 12 years (Farlie 2019; Lynch, 2019). In contrast, a significant proportion of CO<sub>2</sub> emissions are expected to persist in the atmosphere for hundreds of years, or even longer (Farlie, 2019; Lynch, 2019). As a result, the treatment of all GHGs as CO<sub>2</sub> equivalent (CO<sub>2</sub>e) using GWP—and failure to consider the atmospheric removal of SLCPs—misrepresents the impact of methane on future warming (Frame et al., 2018; Cain, 2018). Recognizing this shortcoming, leading climate scientists expanded on GWP and developed GWP\* (GWP-Star), which quantifies a GHG's actual warming potential, instead of just its CO<sub>2</sub> equivalence, by factoring in how much more or less methane is being emitted from a source over a period of time. GWP\* appropriately builds on the conventional GWP approach employed in typical reporting of GHG emissions (Lynch, 2019). GWP\* recognizes the rate and degradation of methane emissions, in addition to the total

amount of CO<sub>2</sub> and other long-lived gases emitted (Lynch, 2019; Cain, 2018; Frame et al., 2018).

### **Climate Impact Potential/GWP\* (GWP-Star)**

Recognizing the important differences in how methane and carbon dioxide affect climate change is critical to quantifying their actual climate impacts. GWP\* was developed to better and more completely account for the warming impacts of short- and long-lived gases and better link emissions to warming (Cain, 2018). GWP\* is still based on GWP, but recognizes how different gases such as methane affect warming (Cain, 2018).

Because CO<sub>2</sub> emissions last in the atmosphere for so long, they can continue to impact warming for centuries to come. New emissions are added on top of those that were previously emitted, leading to increases in the total atmospheric stock or concentration of CO<sub>2</sub>. As a result, when additional CO<sub>2</sub> is emitted, additional global warming occurs (Frame et al., 2018).

In contrast, methane emissions degrade in the atmosphere relatively quickly, after about 12 years, and do not act cumulatively over long periods of time. For a constant rate of methane emissions, one molecule in effect replaces a previously emitted molecule that has since broken down. This means that for a steady rate of methane release—as emitted by a constant number of dairy cows, for example—the amount of methane in the atmosphere (concentration) stays at the same level and does not increase. As a result, when a steady amount of methane is emitted for more than 12 years, no additional global warming occurs (Frame et al., 2018).

This improved understanding of how short-lived versus long-lived emissions affect climate differently is critical to addressing further global warming. Limiting climate change requires that we bring emissions of CO<sub>2</sub> and other long-lived GHGs down to net-zero (Frame et al., 2018). For methane, however, it is possible to have steady ongoing emissions that do not result in additional warming (Frame et al., 2018).

This does not mean that methane can or should be ignored. Increasing methane emissions would result in significant warming. Because of its short-lived atmospheric lifetime, reducing methane emissions can lead to a drop in atmospheric concentration relatively quickly. So, reducing methane emission rates presents an important mitigation opportunity, which could reverse some of the warming the planet has already experienced (Lynch, 2019). Put simply, a reduction in methane emissions has climate cooling effects (Cain, 2018).

### **Climate-Neutral Dairy: Achievable in California's Near Future**

Understanding how methane impacts global warming is critical to understanding the role of dairy production as a contributor to climate change. California's dairy sector is an excellent case in point. It is no longer growing and expanding production. The number of milk cows raised in the state reached a peak in 2008, around the same time that California passed its first climate policy (2006). Since then, the number of cows has declined by a little more than 7 percent

(CDFA, 2017). Total milk production has also decreased in recent years. As a result, the amount of methane in the atmosphere contributed by California milk production is less today than in 2008, as more methane is being removed from the atmosphere each year through its natural breakdown process (biogenic methane cycle) than is created by fewer dairy cows.

California dairy farms are also taking important, voluntary steps to further reduce methane from farms by installing anaerobic digesters designed to capture methane. Other projects, such as compost pack barns and solid separators, are designed to reduce methane production on farms. More than 213 dairy methane reduction projects have been incentivized with state funds to date (CDFA, 2019). These efforts alone are expected to achieve more than 2.2 million additional metric tons of GHG reduction each year, as the projects continue to be implemented (CDFA, 2019). Hundreds of additional dairy methane reduction projects are expected in future years.

As discussed earlier, enteric emissions (belching) from cows account for a significant share (45 percent) of total dairy methane emissions in California. Identifying solutions to reduce these emissions will also be necessary to meet state goals. While research into enteric emission mitigation is being conducted, and some feed additives show promise, commercially proven and cost-effective solutions are not yet available (Webinar on CARB's Analysis of Progress Toward Achieving Methane Emissions Target from Dairy and Livestock Sector, 2020).

Dairy farms also create other GHGs, such as CO<sub>2</sub> and nitrous oxide (N<sub>2</sub>O), from the use of farm equipment for dairy management and the utilization of manure for growing crops. These emissions account for about 20 percent of all GHGs produced by the dairy production sector (Naranjo et al., 2020). Reducing or offsetting these emissions will also be necessary for the state's dairy production sector to achieve climate neutrality, or the point at which operations and resulting emissions are stable and no longer adding to global warming (no net global warming impact). California dairies are also reducing the amount of CO<sub>2</sub> they emit into the atmosphere through the adoption of solar energy and electrification of feed mixing and water pumping operations. Fossil fuel use per unit of milk produced has dropped by 58.5 percent from 1964 to 2014 (Naranjo et al., 2020). As dairy methane emissions are reduced further below current levels, then resulting cooling effects can offset some of the remaining CO<sub>2</sub> and other gases contributed by dairy production.

## Conclusions

A continued focus on methane is necessary, as it is a powerful GHG and an important contributor to climate change. Under all scenarios, methane is significant, second only to carbon dioxide in terms of its overall contribution to global, human-driven climate change (Lynch, 2019). Over the last decade, global methane concentrations have increased (Lynch, 2019). Agriculture, including animal agriculture, is partially responsible for the increase, as dairy and meat production and consumption continue to expand globally, particularly in low- and middle-income countries. That notwithstanding, evidence is growing that shale gas production is a larger source of methane emissions than previously assumed (Howarth, 2019). Like every

sector of the global economy, agriculture must do its part if we are to succeed in achieving the overarching goal of limiting global warming. Equally important, California acting alone cannot accomplish significant global dairy methane emission reductions.

Recognizing how methane impacts global climate is also critical to assessing whether the state and world are on track to meet the goals of the Paris Agreement and limit warming to well below 2°C. Comparing GHGs with each other using GWP\* preserves the link between emissions and warming or cooling of the atmosphere (Schleussner et al., 2019). It also provides an informative and better suited way to assess the relative merits of different options for reducing GHG emissions, especially in ambitious mitigation scenarios (Cain, 2019). More accurate expression of mitigation efforts in terms of their direct contribution to future warming also better informs burden-sharing and long-term policies and measures in pursuit of ambitious global temperature goals (Allen, 2018; Schleussner et al., 2019).

Reducing methane emissions and achieving climate neutrality is no small undertaking. California is among the most efficient producers of milk and dairy products, and its life-cycle carbon footprint (per gallon of milk produced) is among the lowest of any region in the world. Achieving these or similar levels of production efficiency (more milk with fewer cows) is a critical first step for other dairy regions to begin stabilizing methane emissions and work toward climate neutrality. The impact of such an accomplishment would have profound climate effects. Attaining California's level of production efficiency in all global dairy production regions could reduce total global GHG emissions by as much as 1.73 percent (E. Kebreab, calculations based on Naranjo et al., 2020 and FAO & GDP, 2018).

A full understanding of the potential climate impact of all greenhouse gases is also important in ensuring effective policies are developed to address methane and other flow pollutants in line with their effects. Dairy production primarily produces flow emissions (80 percent is methane) with smaller amounts of stock emissions, such as CO<sub>2</sub> and N<sub>2</sub>O (Naranjo et al., 2020). Policy or consumption decisions that trade off and result in greater concentrations of CO<sub>2</sub> and N<sub>2</sub>O, while reducing methane, may ultimately leave a warmer planet behind in the long term (Frame et al., 2018).

Adopting sustainable farming practices to vastly improve production efficiency is probably the single-most important step other dairy-producing countries can take to begin to stabilize regional and global methane emissions and begin to achieve climate neutrality. The United Nations Food and Agriculture Organization (FAO) estimates that improved management practices alone could reduce net global methane emissions by 30 percent (FAO, 2019). These efforts will be critical to reduce livestock methane emissions and present important opportunities for reaching global climate mitigation targets. Further reductions in methane emissions will lead to atmospheric concentrations falling relatively quickly, which could reduce some of the warming already experienced (Lynch, 2019).

## References

- Allen, M.R., Fuglestedt, J.S., Shine, K.P., Reisinger, A., Pierrehumbert, R.T., & Forster P.M. (2016). New use of global warming potentials to compare cumulative and short-lived climate pollutants. *Nature Climate Change*. 6. 773–6. Retrieved from <https://www.nature.com/articles/nclimate2998?cacheBust=1508877188307>
- Allen, M.R., Shine, K.P., Fuglestedt, J.S., Millar, R.J., Cain, M., Frame, D.J., & Macey, A.H. (2018). A solution to the misrepresentations of CO<sub>2</sub>-equivalent emissions of short-lived climate pollutants under ambitious mitigation. *npj Climate and Atmospheric Science*. 1(16). Retrieved from <https://www.nature.com/articles/s41612-018-0026-8>
- California Air Resources Board. (2019, August 12). California 2017 Greenhouse Gas Inventory. Retrieved from [https://www.arb.ca.gov/cc/inventory/data/tables/ghg\\_inventory\\_bygas.pdf](https://www.arb.ca.gov/cc/inventory/data/tables/ghg_inventory_bygas.pdf)
- California Air Resources Board. (2015). California’s methane inventory based on the 2015 edition the CARB greenhouse gas inventory. Retrieved from <https://www.arb.ca.gov/ghg-slcp-inventory>
- California Department of Food and Agriculture. (2019, September 18). CDFA Awards Nearly \$102 Million for Dairy Methane Reduction Projects [Press release]. Retrieved from [https://www.cdfa.ca.gov/egov/Press\\_Releases/Press\\_Release.asp?PRnum=19-085](https://www.cdfa.ca.gov/egov/Press_Releases/Press_Release.asp?PRnum=19-085)
- California Department of Food and Agriculture Dairy Marketing, Milk Pooling, and Milk and Dairy Foods Safety Branches. (2017). [California dairy cows and milk productions]. Unpublished raw historical data.
- Cain, M. (2018). Guest post: A new way to assess ‘global warming potential’ of short-lived pollutants. *Carbon Brief*. Retrieved from <https://www.carbonbrief.org/guest-post-a-new-way-to-assess-globalwarming-potential-of-short-lived-pollutants>
- Cain, M., Lynch, J., Allen, M.R., Fuglestedt, D.J. & Macey, A.H. (2019). Improved calculation of warming- equivalent emissions for short-lived climate pollutants. *npj Climate and Atmospheric Science*. 2(29). Retrieved from <https://www.nature.com/articles/s41612-019-0086-4>
- Dairy Cares. (2019, August 28). Cows vs Cars? [Video file]. Retrieved from <https://www.youtube.com/watch?v=RW8BclS27al&vl=en>
- Dairy Industries International. (2019). Sustainability project aims for net zero climate impact in US Dairy. Retrieved from <https://www.dairyindustries.com/news/32149/sustainability-project-aims-for-net-zero-climate-impact-in-us-dairy/>
- Fairlie, S. (2019). A Convenient Untruth. *Resilience*. Retrieved from <https://www.resilience.org/stories/2019-05-10/a-convenient-untruth/>

FAO. (2019). Five practical actions towards low-carbon livestock. Rome. Retrieved from <http://www.fao.org/documents/card/en/c/ca7089en/>

FAO and GDP. (2018). Climate change and the global dairy cattle sector – The role of the dairy sector in a low-carbon future. Rome. 36 pp. Licence: CC BY-NC-SA- 3.0 IGO. Retrieved from <https://dairysustainabilityframework.org/wp-content/uploads/2019/01/Climate-Change-and-the-Global-Dairy-Cattle-Sector.pdf>

Frame, D., Macey, A.H., & Allen, M. (2018). Why methane should be treated differently compared to long-lived greenhouse gases. The Conversation. Retrieved from <https://theconversation.com/why-methane-should-be-treated-differently-compared-to-long-lived-greenhouse-gases-97845>

Howarth, R. W. (2019). Ideas and perspectives: is shale gas a major driver of recent increase in global atmospheric methane?. Biogeosciences, 16, 3033–3046. Retrieved from <https://doi.org/10.5194/bg-16-3033-2019>

Lynch, J. (2019). Agricultural methane and its role as a greenhouse gas. Food Climate Research Network, University of Oxford. Retrieved from <https://foodsource.org.uk/building-blocks/agricultural-methane-and-its-role-greenhouse-gas>

Naranjo, A., Johnson, A., Rossow, H., & Kebreab, E. (2020). Greenhouse gas, water, and land footprint per unit of production of the California dairy industry over 50 years. Journal of Dairy Science. 103, 3760-3. Retrieved from [https://www.journalofdairyscience.org/article/S0022-0302\(20\)30074-6/fulltext](https://www.journalofdairyscience.org/article/S0022-0302(20)30074-6/fulltext)

Schleussner C., Nauels, A., Schaeffer, M., Hare, W., & Rogelj, J. (2019). Inconsistencies when applying novel metrics for emissions accounting to the Paris agreement. Environmental Research Letters. 14(12). Retrieved from <https://iopscience.iop.org/article/10.1088/1748-9326/ab56e7/meta>

United States Department of Agriculture, National Agricultural Statistics Service. (2019). Milk Production, Disposition, and Income 2018 Summary. Retrieved from <https://usda.library.cornell.edu/concern/publications/4b29b5974>