

## **Dairy Cares Comments on the Draft Analysis of Progress toward Achieving the 2030 Dairy and Livestock Sector Methane Emissions Target**

**July 14, 2021**

Dairy Cares appreciates the opportunity to provide the following comments on the California Air Resources Board's ("CARB") *Draft Analysis of Progress toward Achieving the 2030 Dairy and Livestock Sector Methane Emissions Target* ("Analysis").<sup>1</sup> Dairy Cares represents the California dairy sector, including over 1,200 family dairy farms, leading cooperatives, and major dairy processors.<sup>2</sup> Dairy Cares looks forward to continuing to work with CARB on dairy methane reduction efforts and achievement of the state's Short-Lived Climate Pollutant ("SLCP") Plan and overall climate goals.

Dairy Cares generally agrees with the Analysis conducted by CARB and the estimate of progress toward reductions to date. Dairy Cares does, however, disagree with CARB's incorrect interpretation of SB 1383. SB 1383 only set a 40% reduction target for manure methane from the dairy and livestock sector by 2030. SB 1383 did not set a similar target for enteric methane since feed additives or other measures to reduce enteric methane are not yet commercially available, cost-effective, and approved by the U.S. Food and Drug Administration. As a result, the 9 million metric tons of carbon dioxide equivalent ("MMTCO<sub>2</sub>e") by 2030 reduction target set by CARB is not consistent with SB 1383, appropriate, or achievable at this time. While the situation regarding availability of feed additives or other measures may change in the next several years that would not change the fact the target set by SB 1383 applies only to manure methane emissions. According to CARB's Analysis, dairy manure methane accounts for 10 MMTCO<sub>2</sub>e and an appropriate 40% reduction target would therefore be 4 MMTCO<sub>2</sub>e.

### **Progress to Date**

California family dairy farms are leading change and making significant progress in reducing GHG emissions. Producing a glass of milk from a California dairy cow generates 45% less GHG emissions today than it did 50 years ago.<sup>3</sup> Significant advancements in farming efficiency, feed crop yields, veterinary care, sustainable food practices, and animal nutrition, have helped

---

<sup>1</sup> CARB *Draft Analysis of Progress toward Achieving the 2030 Dairy and Livestock Sector Methane Emissions Target*, (June 2021), available at: <https://ww2.arb.ca.gov/sites/default/files/2021-06/draft-2030-dairy-livestock-ch4-analysis.pdf>.

<sup>2</sup> For more information about Dairy Cares visit [www.dairycares.com](http://www.dairycares.com).

<sup>3</sup> UC Davis CLEAR Center: *Methane Cow and Climate Change: California Dairy's Path to Climate Neutrality*, p. 3, appendix.

reduce the environmental footprint of individual cows. More can and is being done to lower the climate footprint even further. California dairy farm families are working closely with the California Department of Food and Agriculture (“CDFA”) and CARB to further reduce the State’s methane emission inventory. As detailed below, these efforts are making tremendous progress and are providing substantial climate, economic, social, public health, and environmental benefits to the State and to local communities.

The Analysis shows that the dairy sector is projected to achieve significant additional reductions toward the SB 1383 target by 2030 through modifications to manure management systems - primarily using anaerobic digesters - and additional reductions through decreases in animal populations.<sup>4</sup> Manure management projects completed or in development are already projected to account for over 2 MMTCO<sub>2</sub>e of reductions annually. The Analysis also shows that herd population reductions are expected to annually account for an additional 2 MMTCO<sub>2</sub>e of reduction by 2030. Achieving additional reductions will require the dairy and livestock sector to implement additional manure management projects and proven enteric mitigation strategies over the next few years.

However, CARB’s desired target of 9 MMTCO<sub>2</sub>e reduction cannot, and will not, be met without significant State and/or federal funding and incentives. Additional incentives are necessary, as pointed out in the Analysis, to both facilitate and accelerate additional methane reductions in the dairy and livestock sector. The Analysis correctly concludes:

Regardless of the project and technology mix used, the most important factors for achieving the 2030 target are ongoing capital funding for new methane emissions reduction projects, continued revenue streams that incentivize dairy biogas capture and beneficial use, and an available and accepted means of reducing enteric methane emissions.<sup>5</sup>

### **Ongoing Challenges**

As is well documented in the Analysis, challenging sector economics, insufficient availability of public funds, and underdeveloped markets for value-added manure products are ongoing and persistent market barriers for both digester and alternative manure management projects. Additional progress will also require development of dairy digesters or certain types of Alternative Manure Management Program (“AMMP”) projects on smaller dairies in the state. While the total capital cost of these projects is less, the cost per cow is much higher due to diminished economies of scale. Many of these future projects may not be in proximity to one of the existing dairy biogas clusters already in development, resulting in additional costs to interconnect the project to the State’s electric or gas transmission grids. Smaller dairies are also less attractive to dairy digester project developers due to their higher costs, greater risk and longer pay-back periods. As CARB is well aware, dairy digester developers can build projects in other states with far lower capital and ongoing operations and maintenance costs while still receiving similar financial benefits from California’s Low Carbon Fuel Standard (“LCFS”)

---

<sup>4</sup> CARB *Draft Analysis...*, p. ES-2.

<sup>5</sup> *Id.*, p. ES-4.

Program and the federal Renewable Funds Standard program. California’s higher costs and competition from out of state projects further expands the need for additional resources and incentives to achieve greater reductions as sought by the State.

While a continued focus is needed on policies that will broaden adoption of digesters on California dairies, including smaller dairies, it is also essential to consider and prioritize non-digester projects – especially those that can provide significant methane reduction while also managing surplus manure nitrogen and other surplus nutrients. Projects that divert manure away from anaerobic lagoons with the intent of denitrifying the manure via vermiculture (worm composting) or similar biological denitrification, and projects which otherwise divert manure from anaerobic storage for processing and export to other farms provide a huge potential to reduce methane at levels approaching the effectiveness of digesters, while also reducing energy use and GHG emissions related to fertilizer production. Further, these types of projects provide significant promise to not only greatly reduce methane, but also to significantly reduce water quality impacts associated with dairies.

### **Ongoing Funding Needs**

Over the past six years, the California Climate Investment (“CCI”) Program has offset some capital costs of both dairy digester and alternative manure management projects. Approximately \$268 million in CCI funds has been instrumental in funding 233 dairy manure methane reduction projects. Dairy Cares estimates that an additional \$450 million - \$600 million in additional CCI (or other State or federal funding) investments will be necessary to achieve the additional dairy methane reductions sought by CARB. This level of funding will provide grants for 300 to 400 additional manure management projects. The exact number of additional projects needed will depend on the availability of feed additives or other enteric methane reduction strategies and the level of methane reduction they can achieve toward CARB’s desired target. The higher end of this funding range is consistent with CARB staff estimates that are necessary to achieve the expanded emission reductions sought by CARB.

This level of funding is generally consistent with original estimates in the Short-lived Climate Pollutant Plan of \$500 million. This additional funding is also fully consistent with the legislative intent and voluntary incentive-based approach mandated by SB 1383. Finally, this level of funding is fully consistent with the intent of the State’s Cap and Trade and CCI Programs. Dairy methane reduction projects represent important cost-effective investments to significantly reduce GHG in California. The California Department of Food and Agriculture’s Dairy Digester Research and Development Program (“DDRDP”) is the State’s most cost-effective investment, at just \$9 per ton of reduction. The DDRDP is also responsible for achieving 29% of all GHG reductions from all CCI funded programs while receiving just 2.1% of total funds (implemented to date).<sup>6</sup> Put simply, investments in dairy digesters provide 29% of the State’s return with just 2.1% of the investment dollars, a tremendous mitigation opportunity and solid investment for the State.

---

<sup>6</sup> CCI Annual Report for 2021.

Finally, the Analysis correctly concludes, “reducing or eliminating CCI or other public funding for dairy and livestock methane emission reduction projects may eliminate prioritization of projects that deliver important environmental and public health co-benefits.”

### **Additional Targeted Programs, Incentives, and Opportunities**

New and expanded incentives could also expand and accelerate the additional dairy methane reductions sought by the State. Dairy Cares has identified the following:

#### **1. Improved Environmental Credit Certainty**

Enhanced environmental credit certainty has reduced a considerable market barrier to digester project development by helping project developers obtain funding and financing. Two additional incentives should be pursued by the State to further enhance project funding and financing. The first incentive would be implementing a “pilot financial mechanism” as required by SB 1383. As the Analysis notes, CARB staff has developed a white paper on how a pilot financial mechanism could act as a floor price on LCFS credits for in-state digester projects. CARB should now move forward and ensure a pilot financial mechanism is actually implemented and funded to provide further assurance and market stability for LCFS credits. The pilot mechanism can and should be implemented by the Governor’s Office of Business and Economic Development as part of the California Infrastructure and Economic Development Bank Finance Programs or future implementation of a Climate Catalyst Fund. A pilot financial mechanism would be an important complement to State funded loans and loan guarantees.

Additionally, CARB should explore and provide a second 10-year guaranteed crediting period for dairy digester and other methane reduction projects. A second or extended crediting period was also included and intended under SB 1383’s voluntary incentive-based approach to dairy and livestock sector methane reduction. A second or extended guaranteed crediting period would provide additional certainty and reduce risk for project financing, especially on smaller dairies that will require an extended pay-back period due to higher costs. A guaranteed or extended crediting period would also ensure existing projects have a sufficient revenue stream to cover ongoing operations and maintenance costs in the future.

#### **2. Enteric and AMMP Offset Compliance Protocols**

The Cap and Trade Program allows dairy digester developers to quantify the methane emissions reductions resulting from the installation of a digester using the CARB Compliance Offset Protocol for Livestock Projects. These methane emissions reductions can generate carbon offset credits that developers can sell to capped entities.

The existing Compliance Offset Protocol for Livestock Projects should be expanded to include solid separators, scrape or vacuum systems, and other alternative manure management projects. This will provide at least a minimal revenue stream for these projects helping to offset the cost of development and ongoing operation and maintenance costs associated with long-term continued operation.

A new Compliance Offset Protocol for enteric emission reduction strategies, particularly feed additives, should also be pursued and adopted. As documented in the Analysis, methane emissions from enteric fermentation in dairy and livestock account for about 30% of statewide

methane emissions, or approximately 12 MMTCO<sub>2</sub>e annually. Potential strategies to reduce emissions from the digestion process include diet modifications, feed additives, feed efficiency improvements, selective breeding of low methane producing animals, and even mechanical devices that can be worn by animals. Of these, feed additives represent significant potential for sector-wide methane emissions reductions. Feed additives can also potentially deliver considerable methane emission reductions shortly after adoption. Dairy Cares agrees with CARB that certain feed additives show promising methane emission reduction potential, however none are commercially available or have U.S. Food and Drug Administration approval.

In anticipation of these products, and potentially other strategies, Dairy Cares has embarked on development of an enteric emissions reduction protocol which could lead to adoption of a CARB-approved Compliance Offset Protocol. Dairy Cares looks forward to CARB's involvement in its development and adoption.

It is estimated that feed additives, when commercially available, could reduce dairy and beef cattle emissions by 30% or more.<sup>7</sup> The potential reductions are large in scale, perhaps more than 3 MMTCO<sub>2</sub>e annually. However, utilization and effectiveness of feed additives will not be uniform across all cattle and production practices. As these products become commercially available, these limitations must be taken into consideration by CARB as part of any emission reduction targets associated with their use.

Expansion of the existing Compliance Offset Protocol for Livestock Projects and adoption of a new Compliance Offset Protocol for Enteric Emissions will facilitate continued voluntary adoption of AMMP projects and incentivize voluntary adoption of feed additives as they become available and help offset the costs associated with their use.

### **3. Expanded CPUC Incentives and Procurement Opportunities**

The CPUC has also provided important funding for dairy methane production projects to demonstrate biomethane injection into the common carrier pipeline network. One ongoing program administered by the CPUC is the Renewable Gas Pipeline Interconnection Incentive Program, which provides cost share for dairy biomethane pipeline injection projects. The program has provided \$80 million for pipeline injections so far, much of it to dairy digester projects. This funding is currently depleted despite ongoing funding needs for multiple dairy biomethane projects. Continued and expanded funding of this program will be critical as the state seeks to incentivize digesters on smaller dairies.

The BioMAT Program is another important program administered by the CPUC. The BioMAT program has provided long-term power purchase agreements with a guaranteed price to projects that generate electricity delivered to the grid. To date, the BioMAT program has provided contracts for 19 MW of connected load. Continuation of this program will also be essential moving forward, particularly for smaller dairy operations who may not be well positioned for biomethane injection.

Finally, the CPUC is also implementing biomethane and procurement for the state's investor-owned utilities. It will be important for dairy biomethane to be eligible for these long-term (10-

---

<sup>7</sup> CARB *Draft Analysis...*, p. 39.

20 year) fixed price-procurement contracts. Unfortunately, a recent CPUC staff proposal on the implementation of SB 1440 specifically precluded dairy biomethane from procurement under the program. Dairy Cares is hopeful the shortsighted staff proposal will be revisited by the CPUC and corrected. The additional dairy and methane reductions sought by CARB and the State will not materialize without long-term energy offtake procurement opportunities. Excluding dairy biomethane from such programs will have a chilling effect on project financing and create uncertainty in funding markets. CARB must collaborate with the CPUC to ensure all important market opportunities remain available to dairy biomethane and other procurement programs.

### **Methane and Other SLCPs**

The short-term climate benefits of reducing SLCPs, including methane, are well documented. SLCP reductions account for about one-third of the cumulative GHG emissions reductions the State is relying on to achieve the statewide 2030 GHG emissions target established under SB 32.<sup>8</sup> SLCP reductions are also necessary to achieve the State's mid-century carbon neutrality goal.<sup>9</sup>

Short-Lived Climate Pollutants, including methane, are powerful climate gases but have a relatively short atmospheric lifetime. In the case of methane, that lifetime is approximately 10-12 years. As a result, methane reductions achieved now have a short-term beneficial impact on climate change. Accordingly, leading climate scientists and NGOs are now recognizing that moderate reductions in methane emissions can quickly stabilize the climate pollutant's powerful impact, and further reductions can offset the far more persistent warming impacts of carbon dioxide, which accumulate in the atmosphere for hundreds of years.

It is also important to differentiate fossil methane and biogenic methane. Fossil methane, such as natural gas, is carbon that has been locked in the ground for millions of years and is extracted and combusted for use in homes and businesses. The burning of fossil methane directly transfers carbon that was stored in the ground (geologic carbon) into the atmosphere as carbon dioxide (CO<sub>2</sub>). That carbon continues to accumulate and persist in the environment, contributing to climate change for hundreds of years, driving climate warming.

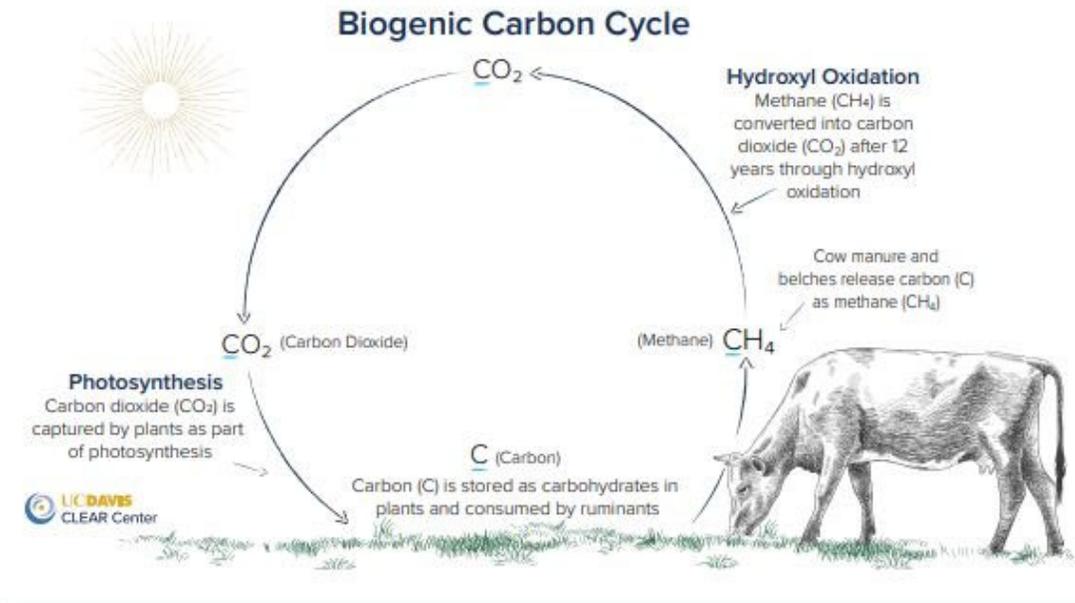
Biogenic methane from cows is part of a natural carbon cycle, where after about 10-12 years it is removed from the atmosphere (short-lived) and does not continue to contribute to warming. As part of photosynthesis, plants capture CO<sub>2</sub> from the atmosphere, absorbing the carbon and releasing oxygen. That carbon is converted into carbohydrates in the plant, which are then consumed by 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> – the same molecules that were consumed by cows in the form of plants. The biogenic carbon cycle returns the carbon that was originally utilized by the plant to the atmosphere, contributing no net gain of CO<sub>2</sub>.<sup>10</sup> The biogenic carbon cycle of dairy methane is depicted in the following diagram, provided by the UC Davis CLEAR Center:

---

<sup>8</sup> CARB *Draft Analysis...*, p. ES-1.

<sup>9</sup> *Id.*, p. 3.

<sup>10</sup> *Methane Cow and Climate Change: California Dairy's Path to Climate Neutrality*, p. 5, appendix.



*As part of the biogenic carbon cycle, the carbon originally utilized by the plant is returned to the atmosphere, contributing no net gain of  $\text{CO}_2$ . Diagram provided by the UC Davis CLEAR Center*

$\text{CO}_2$  produced by the combustion of fossil fuels is fundamentally different.  $\text{CO}_2$  makes up the overwhelming majority of GHG emitted in California and is far more damaging than methane due to its long atmospheric lifetime and its continued accumulation in the environment, adding to continued warming. For these reasons, carbon dioxide, not methane, is the true “super-pollutant” affecting climate change. This improved understanding of how short-lived versus long-lived emissions affect climate differently is critical as CARB seeks further dairy and livestock emission reductions to address additional global warming. Limiting climate change requires that we bring emissions of  $\text{CO}_2$  and other long-lived GHGs down to net-zero. For methane, however, it is possible to have steady ongoing emissions that do not result in additional warming.<sup>11</sup>

The short-lived atmospheric lifetime associated with methane reductions can result in a relatively quick drop in atmospheric concentration. As a result, reducing methane emission rates presents an important mitigation opportunity which can reverse some of the warming the planet has already experienced.<sup>12</sup> The value of these mitigation opportunities should be analyzed and included all future discussions about SLCP reductions as well as in the 2022 Scoping Plan.

It should also be noted, California’s dairy sector is already contributing less methane (and as a result, less global warming impact) than it was in 2008 because the state is home to extensive manure methane reduction efforts and fewer dairy cows today than in 2008. Put simply, more methane from the California dairy sector is currently leaving the atmosphere each year than is being produced and added.

<sup>11</sup> Frame, D., Macey, A.H., & Allen, M. (2018). Why methane should be treated differently compared to long-lived greenhouse gases. The Conversation.

<sup>12</sup> Lynch, J. (2019). Agricultural methane and its role as a greenhouse gas. Food Climate Research Network, University of Oxford.

## Dairy Methane Reduction Efforts Moving Forward

As the Analysis documents, the dairy sector is on a path toward achieving the target of reducing methane emissions 40% below 2013 levels by 2030, already projected to accomplish more than 4 MMTCO<sub>2</sub>e of reductions.<sup>13</sup> Progress is being made from modifications to manure management systems—primarily using anaerobic digesters—and additional reductions through decreases in animal populations. These efforts will need to continue over the remainder of this decade to help achieve the State’s SLCP targets and any additional dairy and livestock sector emission reductions sought by CARB.

The Analysis documents the “insufficient availability of public funds” as a leading market barrier for manure management project expansion in the dairy sector.<sup>14</sup> As already discussed, the SLCP plan recommended a minimum funding amount of at least \$100 million per year for five years as necessary to accelerate project development by offsetting capital costs and economic risks for manure management methane emissions reduction projects. To date, just \$268 million has been provided, an insufficient amount to achieve the 2030 target. The FY 2019-2020 CCI allocation of \$34 million was considerably lower than the \$99 million available in FY 2017-2018 and FY 2018-2019, falling \$66 million short of annual funding needs. The proposed FY 2020-2021 allocation of \$20 million did not materialize due to budget cuts. The FY 2021-2022 proposed allocation of \$60 million has not been finalized. Finally, as the Analysis points out, “while dairy digesters offer significant and cost-effective methane emissions reductions, without large-scale public incentives, the rate of adoption would likely decrease greatly.”<sup>15</sup> Additional funding for dairy manure methane efforts must be provided if the State is to meet the dairy and livestock sector methane reduction goals sought by CARB.

Efforts to reduce enteric emissions through genetic selection, diet modification, and feed additives are also being pursued, and are critical to achieving livestock methane reduction goals. Extensive research and product development is being undertaken to make feed additives commercially available, and Dairy Cares agrees with CARB that conducting additional research on emerging enteric emission reduction strategies is warranted. Dairy Cares is also pursuing development of a voluntary enteric emissions protocol to monetize reductions and incentivize usage. SB 1383 requires a voluntary incentive-based strategy for enteric emissions reductions, and Dairy Cares looks forward to development of a CARB approved Compliance Offset Protocol.<sup>16</sup>

### Proven Environmental and Community Benefits of Methane Reduction Projects

Dairy digester and other livestock methane reduction efforts also provide well-documented direct and indirect benefits to the State and to local communities. Despite these benefits, digester projects and other emission reduction efforts have faced opposition by various environmental justice advocates such as the Disadvantaged Communities Advisory Group (“DACAG”) and

---

<sup>13</sup> CARB *Draft Analysis...*, p. 7.

<sup>14</sup> *Id.*, p. ES-3.

<sup>15</sup> *Id.*, p. 16.

<sup>16</sup> Health & Saf. Code § 39730.7(f).

other parties before the CPUC and other State agencies.<sup>17</sup> While Dairy Cares does not agree with the opposition of these groups to methane reduction efforts, we do appreciate CARB's responsibility to evaluate the impacts and benefits of various climate strategies on front-line communities and ensure that the Analysis appropriately reflects the overall significant benefits of dairy methane reduction efforts.

Three recent reports from CARB and CDFA document the significant environmental, climate, social, and economic benefits of dairy digesters and dairy methane reduction efforts. These benefits include significant direct and indirect benefits to local disadvantaged communities and priority populations.

### **1. California Climate Investments - 2021 Annual Report**

- Documents that the dairy digester program is responsible for achieving **29% of all GHG reductions** from all programs invested in by the State with just 2.1% of total funds implemented.
- Identifies the dairy digester program as the State's **most cost-effective program**, at just \$9 per ton of reduction.
- Reports that **66%** of funds expended on dairy digesters **benefit priority populations**.

### **2. California Department of Food and Agriculture - Report of Funded (Dairy Digester Research and Development Program) Projects**

- Estimates the cumulative reduction from the dairy digester program as 21.12 million metric tons MMTCO<sub>2e</sub> over 10 years or 2.1 1 MMTCO<sub>2e</sub> annually.
- Documents the environmental protection of water and air quality.
- Identifies significant air, water quality, and nuisance (odor) benefits provided to local communities.

### **3. California Air Resources Board Analysis of Progress toward Achieving the 2030 Dairy and Livestock Sector Methane Emissions Target**

- Documents the progress toward the targeted livestock sector methane reductions.
- Identifies the need for additional incentives and grant funding.
- Estimates the societal benefits of reducing methane emissions at up to \$2.46 billion.
- Confirms the 40% targeted reduction in dairy and livestock methane cannot be achieved without significant additional digester development.
- Recognizes that the voluntary, incentive-based approach has helped fund projects that provide additional environmental benefits, including improved air quality and water quality protection.

---

<sup>17</sup> See for example, CPUC Application 19-02-015, DACAG December 2, 2020 Letter to California Public Utilities Commissioners. See also, CPUC OIR 13-02-008, Comments of Leadership Council for Justice and Accountability, Food & Water Watch, pp. 4 -9 (June 30, 2021), available at: <https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M389/K957/389957229.PDF>.

In addition, a recent Global Methane Assessment<sup>18</sup> conducted by the United Nations Environment Programme emphasizes the need to further abate methane as a short-term hedge against the more damaging and long-term impacts of CO<sub>2</sub>, the primary GHG causing global warming. The UN report recognizes the importance of improved farm management efficiency and productivity. It also specifically identifies livestock manure management, including treatment in biogas digesters and improvements in manure storage covering as critical targeted measures for the agriculture sector.<sup>19</sup> Notably, the target measures identified by the UN are fully consistent with CARB's own SCLP policies, including the important role of dairy methane reduction and utilization of dairy digesters.

### **Conclusion**

The dairy and livestock sector is well-positioned and has made substantial progress toward achieving the target of reducing methane emissions 40% below 2013 levels by 2030. However, CARB's additional targeted reductions can only be achieved with significant additional public funding and incentives to facilitate development of additional manure methane reduction projects as well as the development of cost-effective voluntary incentive-based enteric reduction opportunities. Maintaining the overall voluntary incentive-based approach for dairy methane reduction, as envisioned and mandated by SB 1383, will also be critical moving forward. Alternative regulatory-based approaches will fail to achieve the desired reductions, lead to methane emission leakage, and result in higher overall global methane emissions as production simply shifts to regions with higher emissions per gallon of milk produced.

Finally, Dairy Cares recommends CARB incorporate the role of SLCP reductions as a short-term hedge against long-term CO<sub>2</sub> impacts. The 2022 Scoping Plan should consider and address climate impacts of biogenic dairy methane emissions going forward. Rethinking methane's role in climate policy is important and the 2022 Scoping Plan is the appropriate venue for such analysis. Appropriate goals, policies, and required incentives should be identified and set for methane, recognizing its tremendous mitigation potential in the short-term.

---

<sup>18</sup> United Nations Environment Programme and Climate and Clean Air Coalition (2021). *Global Methane Assessment: Benefits and Costs of Mitigating Methane Emissions*, available at: <https://www.unep.org/resources/report/global-methane-assessment-benefits-and-costs-mitigating-methane-emissions>.

<sup>19</sup> *Id.*, p. 16

# APPENDIX 1

UC Davis CLEAR Center

**Methane, Cows, and Climate Change:** California Dairy's Path to  
Climate Neutrality

September 2, 2020



## **Methane, Cows, and Climate Change:** California Dairy's Path to Climate Neutrality

### **CLEAR Center**

1103 Meyer Hall  
One Shields Ave  
Davis, CA 95616  
United States

#### **Media Contact:**

Joe Proudman  
jproudman@ucdavis.edu  
530-564-2734

### **Dr. Frank Mitloehner**

Professor and Air Quality Specialist  
Director, CLEAR Center  
University of California, Davis

### **Dr. Ermias Kebreab**

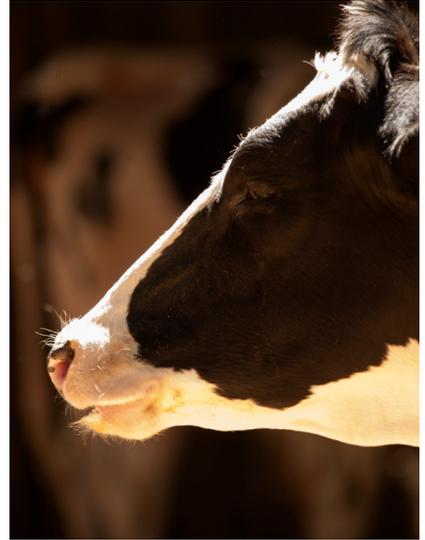
Professor and Sesnon Endowed Chair  
Director, World Food Center  
University of California, Davis

### **Michael Boccadoro**

Executive Director  
Dairy Cares

# 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 dairies reduced emissions by 45% between 1964-2014.

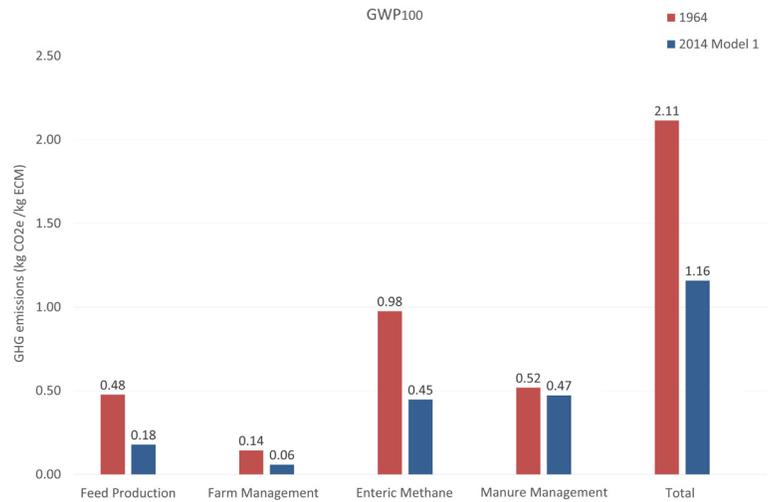


Figure 1. Comparison of global warming potential (GWP) in 1964 and 2014 by emission source for model 1 (using farm sampled diets). GHG = greenhouse gas; CO<sub>2</sub>e = CO<sub>2</sub> equivalents. - Journal of Dairy Science, Naranjo et. al., 2020

## California's Greenhouse Gas Emissions

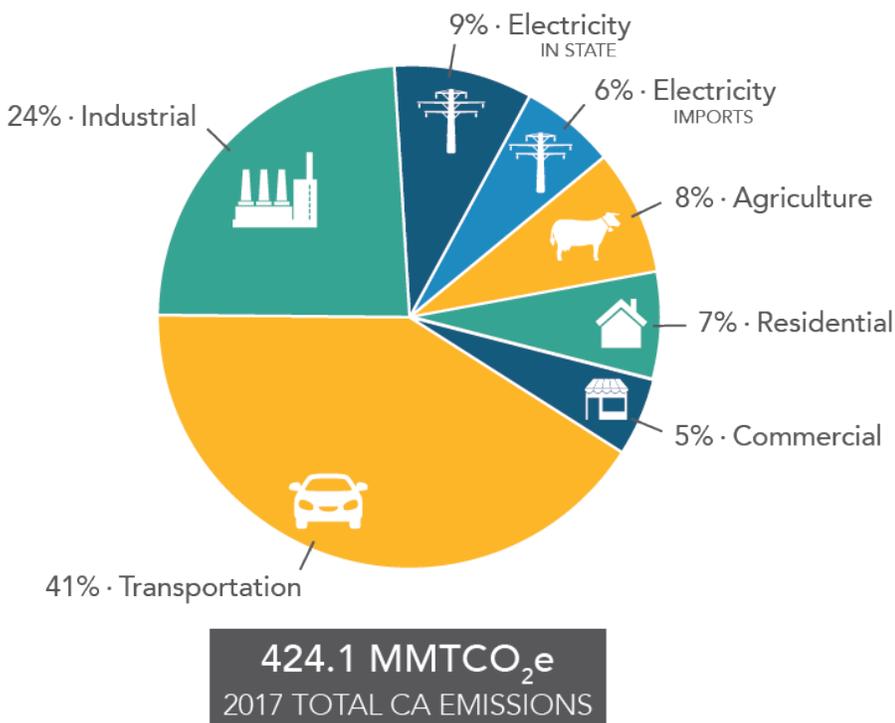
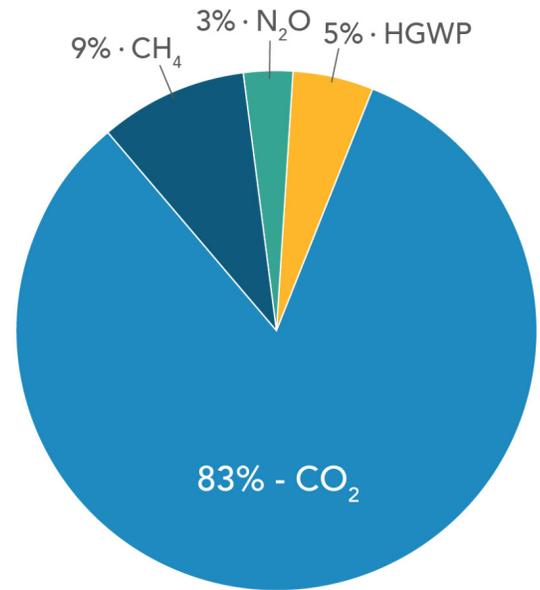


Figure 2. 2017 California greenhouse gas emissions by sector. Source: CARB.

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).



**429.4 MMTCO<sub>2</sub>e**  
2016 TOTAL CA EMISSIONS

Figure 3. 2017 California greenhouse gas inventory. Source: CARB.

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.

**2013 Methane: 118 MMTCO<sub>2</sub>e (20-yr GWP)**

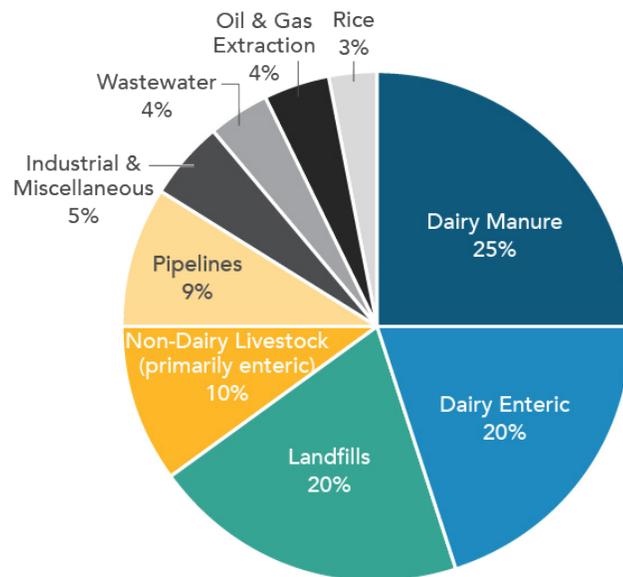


Figure 4. 2015 California methane inventory. Source: CARB.

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  $\text{CO}_2$ . 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  $\text{CO}_2$  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 ( $\text{CH}_4$ ). After about 12 years in the atmosphere, that methane is oxidized and converted into  $\text{CO}_2$ . 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  $\text{CO}_2$ .**

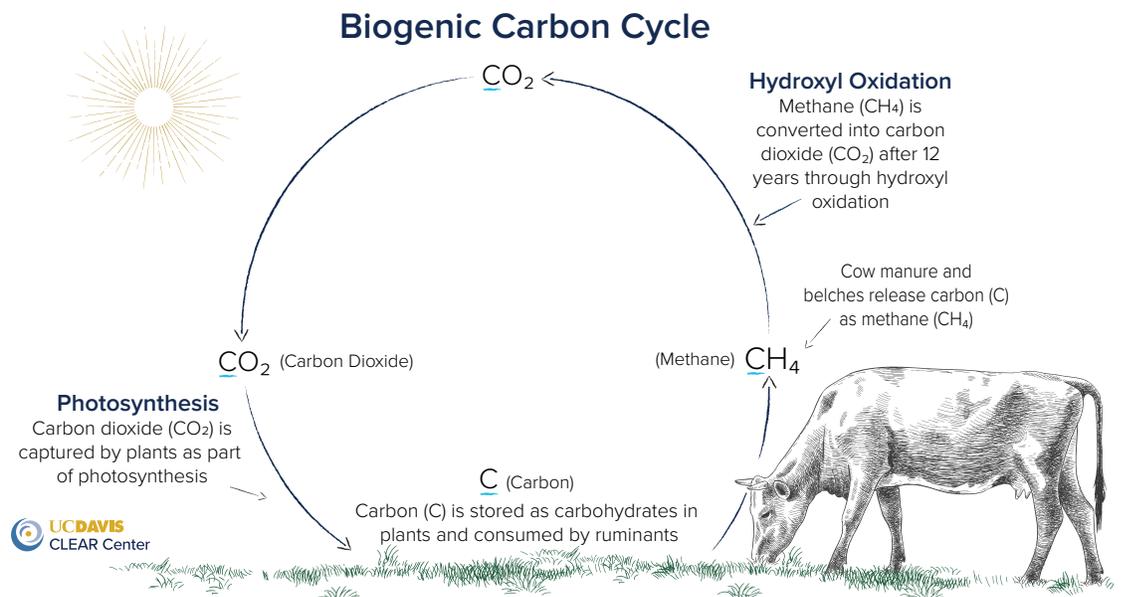
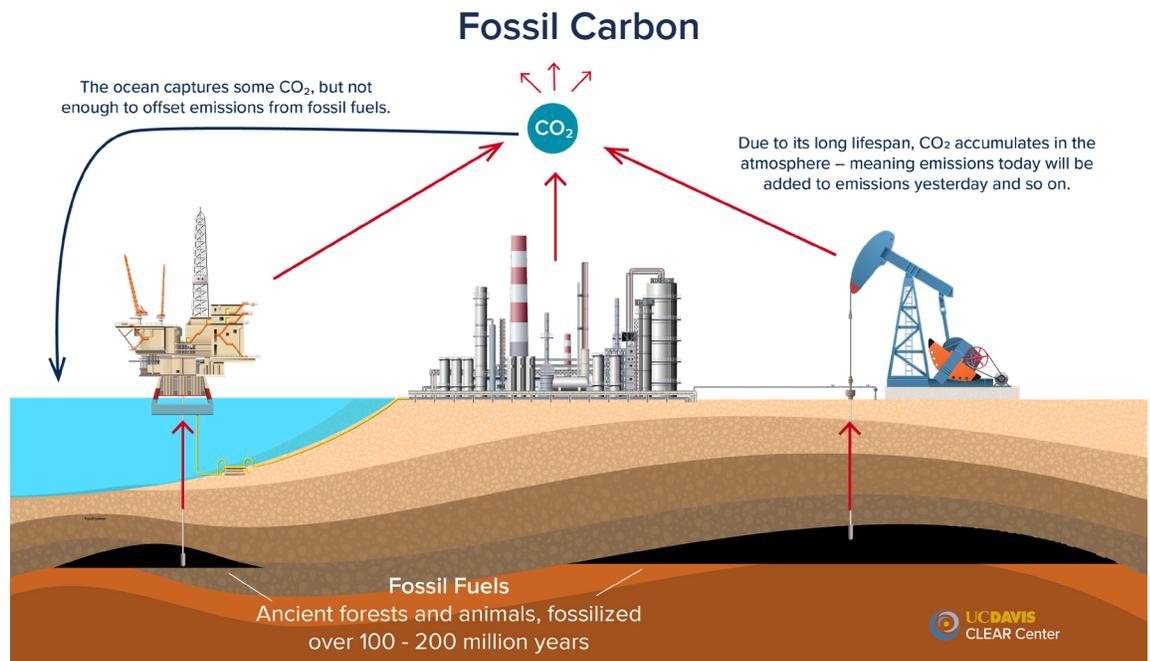


Figure 5. Top, the biogenic carbon cycle shows how carbon moves from the atmosphere to plants, and then to animals, and then back into the atmosphere. This process is further explained in the CLEAR Center video “Rethinking Methane.”

Figure 6. Bottom, the burning of geologic carbon – including fossil methane – is a one-way process, resulting in  $\text{CO}_2$  accumulating in the atmosphere.



# 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).

**Global Warming Potential (GWP<sub>100</sub>) of Main Greenhouse Gases**

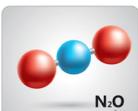
|   | AR4 | AR5 |
|---|-----|-----|
|  Carbon Dioxide (CO <sub>2</sub> ) | 1   | 1   |
|  Methane (CH <sub>4</sub> )        | 25  | 28  |
|  Nitrous Oxide N <sub>2</sub> O    | 298 | 265 |

Table 1. This table is adapted from the IPCC Fourth Assessment Report (AR4), 2007 and the IPCC Fifth Assessment Report (AR5), 2014. Note, CARB uses AR4.

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

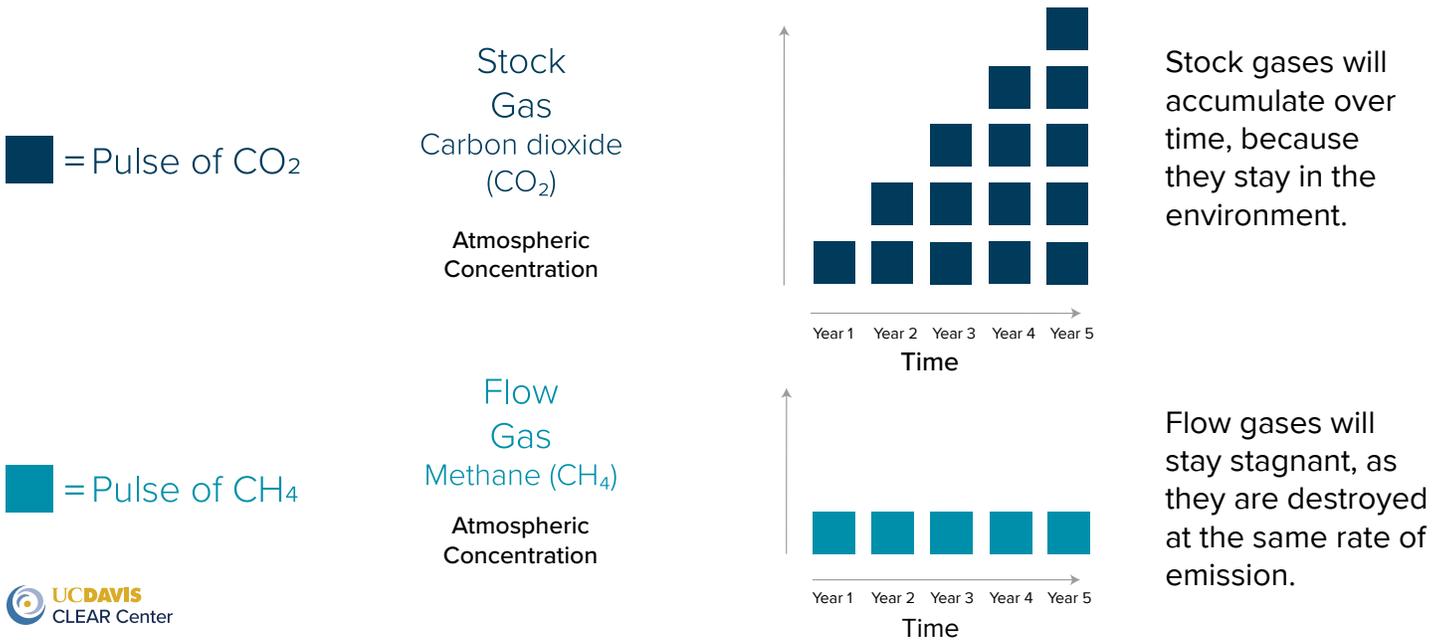
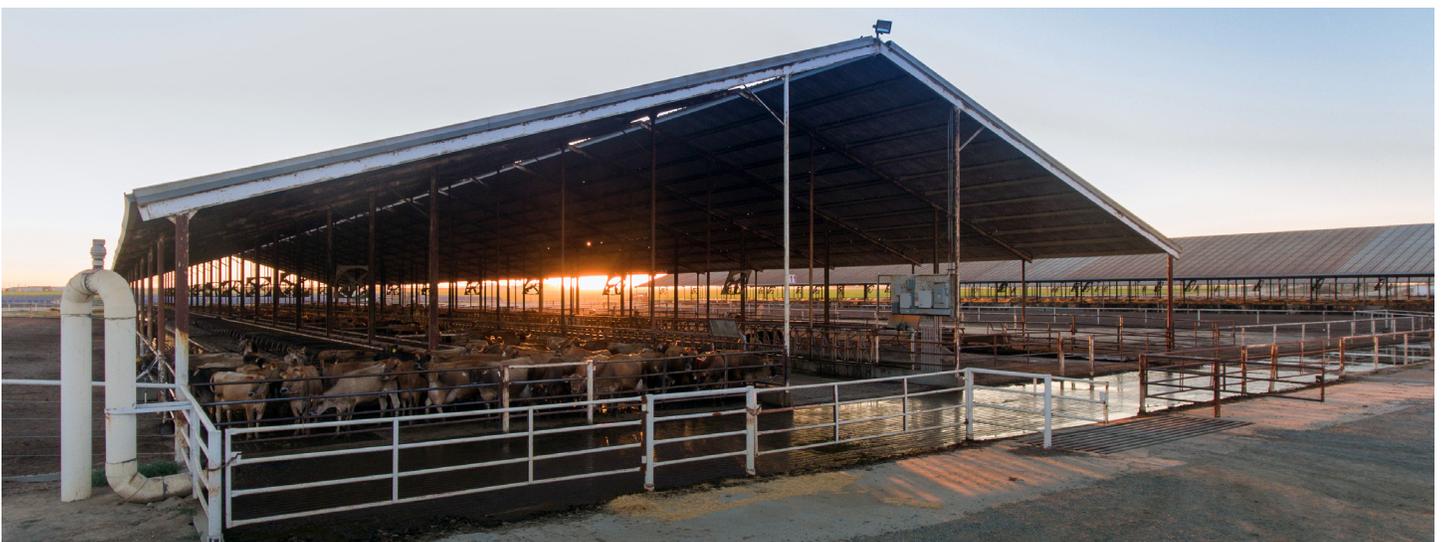


Figure 7. Based on research by Myles R. Allen, Keith P. Shine, Jan S. Fuglestedt, Richard J. Millar, Michelle Cain, David J. Frame & Adrian H. Macey. Read more here: <https://rdcu.be/b1t7S>

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.

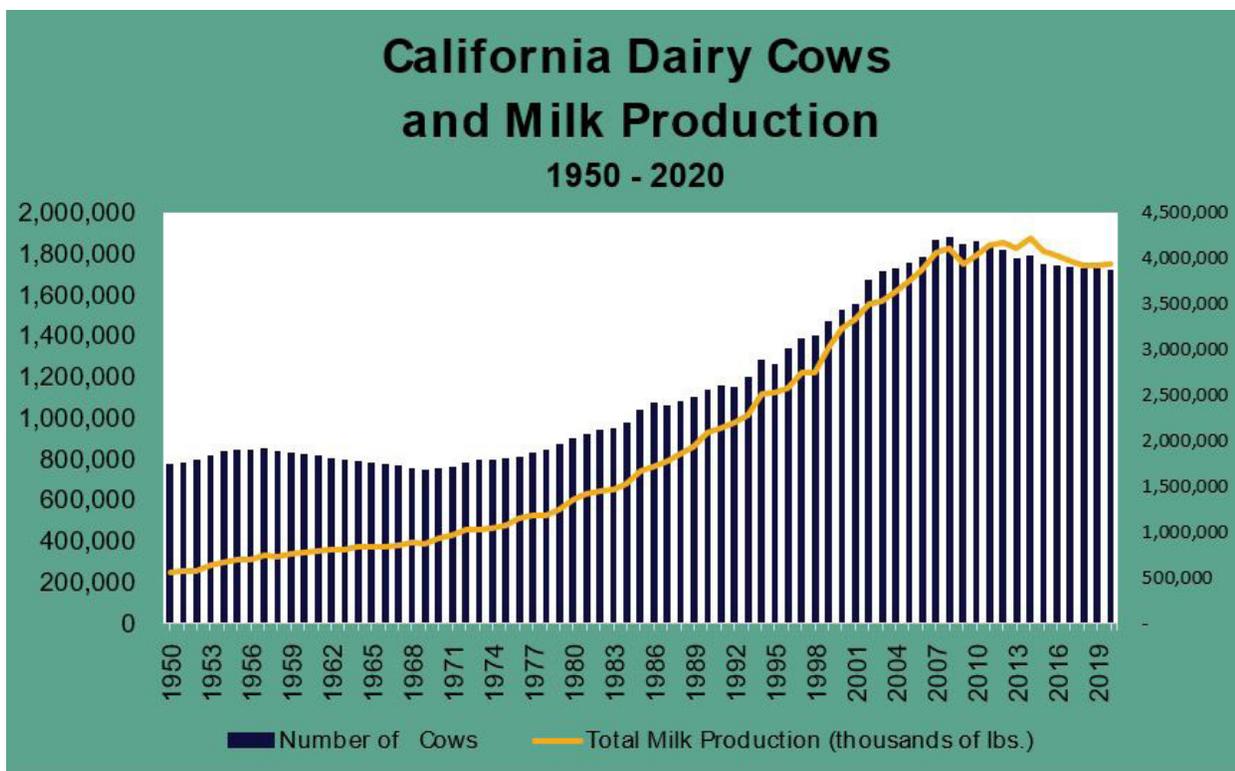


Figure 8. Number of California Dairy Cows and Volume of Milk Production: Sources: CDFA Dairy Marketing, Milk Pooling, and Milk and Dairy Foods Safety Branches; USDA Milk Production Report

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.



Figure 9. Manure solid separator, climate-smart dairy project on a California dairy farm.

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).

**What is Climate Neutrality?**  
*Climate neutrality is when an entity or industry has no net global warming impact. Same as “warming neutral.”*

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 and Policy Considerations

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.

A renewed focus on how we consider and address the climate impact of methane emissions is also warranted (Lynch, 2019). As discussed in this paper, rethinking methane's role in climate is important, because there are significant differences in how methane and carbon dioxide—the main human-generated GHG—affect climate (Lynch, 2019). Different goals should be identified and set for CO<sub>2</sub>, CH<sub>4</sub>, and other GHGs. Designing effective policies to limit global warming also requires knowledge of how different mitigation measures impact temperature, including in targeting appropriate programs to incentivize voluntary adoption of methane reduction technologies and practices. Voluntary dairy methane reduction will need to be continued, as it is an important climate mitigation tool.

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).



Figure 10. California climate-smart dairy with a digester, manure solid separator, and solar installation.



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).

*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.*

California's experience and efforts have identified crucial approaches that have worked to create low-carbon livestock and reduce the climate impacts of dairy production. 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).

# CASE STUDY: CALIFORNIA DAIRY METHANE REDUCTION

Fully understanding the climate cooling potential of dairy methane reduction efforts in California is critical for state regulators and policymakers. California is seeking to reduce dairy methane emissions by roughly 7.2 million metric tons (MMT) per year by 2030 (40% reduction). What will this mean for California’s overall emissions reduction goal of being “net zero” by 2045?



Figure 11. Digester on California dairy farm.

Achieving the state’s goal of reducing dairy methane emissions by 7.2 MMTCO<sub>2</sub>e annually will provide about 20 MMT of annual reduction (cooling) equivalent each year from 2030 to 2045. These reductions will be critical to mitigate continually accumulating CO<sub>2</sub> emissions from other sectors of the economy, and the achievement of the state’s “net zero” long-term goal. In the race to manage global warming, reducing methane can provide fast returns.

This analysis using GWP\* shows the true value of the state’s dairy methane reduction efforts and programs such as CDFA’s Dairy Digester Research and Development Program (DDRDP) and Alternative Manure Management Program (AMMP), which are expected to incentivize more than half of the 7.2 MMT of methane reduction. This analysis also underscores the importance of continuing to fully fund these California Climate Investment Programs at a minimum of \$85 million per year. (CARB Preliminary Analysis of Dairy Methane Reduction Progress, May 2020).

## Cumulative Overview of the DDRDP & AMMP

| Program   | Number of Projects Funded                                   | Total State Funding Awarded | Total GHG Reductions   | State Cost Per 1 Ton GHG Reduced               |
|---|---|-----------------------------|--|--|
| Dairy Digester Research and Development Program (DDRDP) | <b>108</b><br><small>(total 2015, 2017, 2018, 2019)</small> | <b>\$181.6 million</b>      | <b>19.7 million MTCO<sub>2</sub>e</b><br><small>(10-yr project life)</small> | <b>\$9</b><br><b>Ranked #2 of 68 programs</b>  |
| Alternative Manure Management Program (AMMP)            | <b>105</b><br><small>(total 2017, 2018, 2019)</small>       | <b>\$63 million</b>         | <b>1.1 million MTCO<sub>2</sub>e</b><br><small>(5-yr project life)</small>   | <b>\$49</b><br><b>Ranked #7 of 68 programs</b> |

Sources: Report of Funded Projects - CDFA DDRDP 2020; Report of Funded Projects - CDFA AMMP 2020; California Climate Investments 2020 Annual Report

# ABOUT THE AUTHORS

**Frank Mitloehner, Ph.D., Professor and Air Quality Specialist, Director, CLEAR Center, UC Davis**



Frank Mitloehner is a professor and air quality specialist for Cooperative Extension in the Department of Animal Science at the University of California, Davis. Dr. Mitloehner has served as chairman of a global United Nations Food and Agriculture Organization partnership project to benchmark the environmental footprint of livestock production. Dr. Mitloehner serves as the North American scientific lead for the Global Feed LCA Institute. Dr. Mitloehner is a work group member of the President's Council of Advisors on Science and Technology (PCAST) and a member of the National Academies of Science Institute of Medicine (IOM) committee on "A Framework for Assessing the Health, Environmental, and Social Effects of the Food System."

**Ermias Kebreab, Ph.D., Professor and Sesnon Endowed Chair, Director, World Food Center, Associate Dean of Global Engagement, UC Davis**



Ermias Kebreab serves as the Sesnon Endowed Chair in Sustainable Animal Agriculture at the Department of Animal Science, UC Davis. Dr. Kebreab was appointed Associate Dean of Global Engagement and Director, World Food Center in 2018. He is a contributing author to the 2019 Intergovernmental Panel on Climate Change (IPCC) guideline and chairs the feed additive committee at the Food and Agriculture Organization of the United Nations. Dr. Kebreab conducts research on reducing the impact of animal agriculture on the environment, including the sustainable use of feed additives. Dr. Kebreab received several awards, including International Agriculture Award and AFIA Ruminant Nutrition Award from American Society of Animal Science.

**Michael Boccadoro, Executive Director, Dairy Cares**



With more than 30 years of experience in the public affairs arena, Michael Boccadoro has distinctive expertise in the areas of energy, environmental regulation, and sustainability. Mr. Boccadoro serves as the Executive Director of Dairy Cares, a statewide coalition that works to ensure the long-term sustainability of California's family dairy farms. He has been at the forefront of California's dairy methane reduction efforts and the development of incentive programs to encourage voluntary implementation. Mr. Boccadoro received his Bachelor of Arts degree in economics and political science from the University of California, Davis.

# 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-slcg-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=RW8BcIS27al&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>



## Appendix B: Calculation of GHG reductions to be achieved if all global dairy production regions achieved the same level of production efficiency (carbon intensity).

1. Obtain California dairy industry's carbon intensity, or kg of CO<sub>2</sub>e per kg of energy and-protein corrected milk (ECM). Highlighted in green.

[https://www.journalofdairyscience.org/article/S0022-0302\(20\)30074-6/fulltext](https://www.journalofdairyscience.org/article/S0022-0302(20)30074-6/fulltext)

2. Obtain carbon intensity data for dairy regions throughout the globe:

<https://dairysustainabilityframework.org/wp-content/uploads/2019/01/Climate-Change-and-the-Global-Dairy-Cattle-Sector.pdf>

3. Calculate percent of GHG reduction that would be achieved if the entire global dairy sector achieved California's carbon intensity, using both models.

| REG_ANNEX5                  | 2015 Data                 |             |                 |                               | Business As Usual                   | IF production was like CA model 2   |                        | IF production was like CA model 1   |                        |
|-----------------------------|---------------------------|-------------|-----------------|-------------------------------|-------------------------------------|-------------------------------------|------------------------|-------------------------------------|------------------------|
|                             | Billion kg milk           | % share     | Billion kg FPCM | kg CO <sub>2</sub> e/ kg FPCM | billion kg CO <sub>2</sub> e/region | billion kg CO <sub>2</sub> e/region | % reduction by country | billion kg CO <sub>2</sub> e/region | % reduction by country |
| Central & South America     | 80.75                     | 12.0%       | 80.87           | 3.36                          | 271.7232                            | 90.5744                             | 67%                    | 93.8092                             | 65%                    |
| East Asia                   | 53.19                     | 8.1%        | 54.4            | 2.43                          | 132.192                             | 60.928                              | 54%                    | 63.104                              | 52%                    |
| Eastern Europe              | 42.06                     | 6.3%        | 42.68           | 1.34                          | 57.1912                             | 47.8016                             | 16%                    | 49.5088                             | 13%                    |
| North America               | 102.07                    | 14.5%       | 97.41           | 1.29                          | 125.6589                            | 109.0992                            | 13%                    | 112.9956                            | 10%                    |
| Oceania                     | 31.43                     | 5.1%        | 34.07           | 1.31                          | 44.6317                             | 38.1584                             | 15%                    | 39.5212                             | 11%                    |
| Russian Federation          | 30.52                     | 4.6%        | 31.03           | 1.39                          | 43.1317                             | 34.7536                             | 19%                    | 35.9948                             | 17%                    |
| South Asia                  | 97.39                     | 14.6%       | 98.55           | 4.1                           | 404.055                             | 110.376                             | 73%                    | 114.318                             | 72%                    |
| Sub-Saharan Africa          | 22.04                     | 3.4%        | 23.18           | 6.67                          | 154.6106                            | 25.9616                             | 83%                    | 26.8888                             | 83%                    |
| West Asia & Northern Africa | 60.31                     | 9.2%        | 62.12           | 4.41                          | 273.9492                            | 69.5744                             | 75%                    | 72.0592                             | 74%                    |
| Western Europe              | 146.73                    | 22.1%       | 149.1           | 1.37                          | 204.267                             | 166.992                             | 18%                    | 172.956                             | 15%                    |
| <b>Global</b>               | <b>666.49</b>             | <b>100%</b> | <b>673.41</b>   |                               | <b>1711.4105</b>                    | <b>754.2192</b>                     | <b>56%</b>             | <b>781.1556</b>                     | <b>54%</b>             |
| california model 2          | CDFA model                |             |                 | 1.12                          |                                     |                                     |                        |                                     |                        |
| california model 1          | sampled dairies model CAD |             |                 | 1.16                          |                                     |                                     |                        |                                     |                        |

4. Convert "Business as Usual" Global Dairy CO<sub>2</sub>e into MTCO<sub>2</sub>e.

5. Obtain Total Global GHG emissions data: <https://www.ipcc.ch/site/assets/uploads/2018/12/UNEP-1.pdf>

6. Calculate Percent of Total Global GHG emissions that would be reduced if entire global dairy sector achieved California's carbon intensity, using both models.

|   | IF production was like CA model 2 | IF production was like CA model 1 |
|---|-----------------------------------|-----------------------------------|
| Global Dairy GHG Emissions (BAU) (MTCO <sub>2</sub> e)                | 1,711,800,000                     |                                   |
| Total Global GHG Emissions (Gigatons)                                 | 53.5                              |                                   |
| Total Global GHG Emissions (MTCO <sub>2</sub> e)                      | 53,500,000,000                    |                                   |
| Global Dairy Emissions (at CA carbon intensity) (MTCO <sub>2</sub> e) | 754,390,853                       | 781,333,383                       |
| Percent of Total Global GHGs reduced                                  | 1.79%                             | 1.74%                             |