Meeting the Call

How California is Pioneering a Pathway to Significant Dairy Sector Methane Reduction

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CDRF manages many successful and unique programs, such as the world-class producers' education program "California Dairy Quality Assurance Program," the collaborative pre-competitive interactive "International Milk Genomics Consortium" and various "Industry Outreach" programs, including short courses and symposia that provide short- and long-term technical training and information technology transfer to all relevant parties.

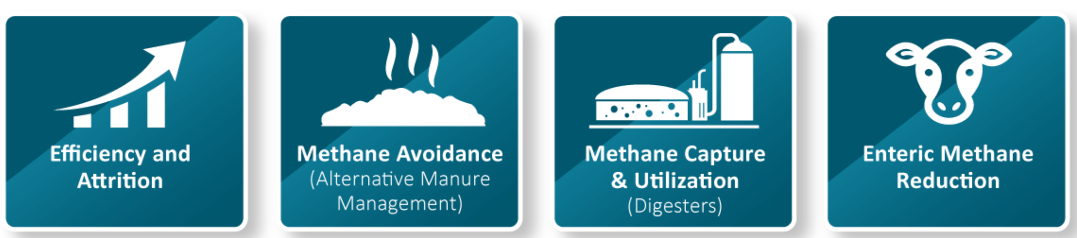
CDRF is governed by a Board of Directors who are drawn from key dairy producer and processor organizations that represent multiple perspectives within the dairy industry.

Executive Summary

The importance of reducing methane emissions as a core climate protection strategy is well documented. According to the 2021 Global Methane Pledge, announced at COP 26 in Glasgow, “Rapidly reducing methane emissions from energy, agriculture, and waste can achieve near-term gains in our efforts in this decade for decisive action and is regarded as the single most effective strategy to keep the goal of limiting warming to 1.5˚C within reach while yielding co-benefits including improving public health and agricultural productivity.”[1]

Well before the release of the UNEP Global Methane Assessment, California had set aggressive targets for reducing methane 40 percent below 2013 levels by 2030, including from the dairy and other livestock sectors (See SB 1383 [Lara, 2016]). This paper focuses on California’s world-leading efforts to reduce dairy sector methane. California’s dairy sector has embraced these goals and made tremendous progress toward this target in the five-plus years since its enactment. Our analysis shows that California’s dairy sector is well on its way to achieving the targets, as recently acknowledged by the California Air Resources Board.[2] Equally important, our analysis documents significant additional reduction efforts that are already funded and occurring and lays out a workable path forward that should enable the California dairy sector to make its proportionate contribution to the 40 percent reduction goal. Our analysis suggests that the comprehensive GHG reduction strategies being implemented will also allow the California dairy industry to achieve “climate neutrality” by 2030.

Figure 1. *California’s dairy methane reduction efforts have employed a comprehensive and successful four-part strategy:*



[1] See https://www.globalmethanepledge.org/

[2] *Analysis of Progress toward Achieving the 2030 Dairy and Livestock Sector Methane Emissions Target, Final*, California Air Resources Board, March 2022. https://ww2.arb.ca.gov/sites/default/files/2022-03/final-dairy-livestock-SB1383-analysis.pdf (Hereafter called “Analysis of Progress” report). In this important report, ARB documents that more than half of the needed methane emission reductions are already in progress.

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Our analysis shows that continued implementation and commitment to the incentive-based climate-smart solutions that are currently driving voluntary dairy methane reduction in California should, by 2030, achieve the full 40 percent reduction in dairy methane sought by state regulators without the need for direct regulation. Ongoing improvements in milk production and attrition in milk cow numbers in the state will play a significant and increasing role in methane reductions, contributing a 2.6 to 3.3 MMTCO2e reduction annually. Utilization of alternative and advanced manure management practices, which recently received substantial additional funding from both federal and state climate-smart dairy programs will reduce between 0.6 and 1.1 MMTCO2e in methane annually by 2030. Continued implementation of dairy manure digesters, which capture fugitive methane for beneficial reuse as renewable fuel replacing diesel in heavy duty trucks is expanding rapidly and will deliver another approximately 4 MMTCO2e of reduction annually by 2030. Finally, the projected commercial availability of and utilization of cost effective and safe feed additives will provide significant additional dairy methane reductions, ranging from 250,000 MTCO2e annually to over 2 MMTCO2e, depending on reduction efficiency and the ultimate rate of adoption by dairy farms in the state.

All total, these strategies are likely to achieve the dairy methane emission sought by the California Air Resources Board. The methane reductions from programs and projects in place today, coupled with the implementation of a moderate feed additive strategy to reduce enteric emissions, is on track to reduce methane between 7.6 to 10.6 MMTCO2e by 2030, **from the dairy sector alone.**

Table 1. California Dairy Methane Reductions Projected to Exceed SB 1383 Requirements

Projected Dairy Sector Methane Reductions	
Reduction Type	**Expected Dairy Emission Reductions Through 2030 (MMTCO2e)**
Herd Reduction	2.61 – 3.3
Anaerobic Digestion	4.15
Alternative Manure Management Practices	0.6 - 1.1
Enteric Emission Reduction Strategies	0.25 – 2.04
Total	**7.61 – 10.59**

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The analysis also shows that misguided efforts to change course by forced conversion to pasture-based operations, direct regulation of dairy farms, or limitations on dairy digester incentives will not only fail to achieve the desired greenhouse gas emission reductions but will exacerbate the problem by causing significant emissions "leakage". As demand for dairy products continues to increase across the U.S. and world, the dairy industry is likely to respond to costly direct regulation by leaving for states with less costly regulations and less commitment to climate protection.

> ***"Our analysis shows that continued implementation and commitment to the incentive-based climate-smart solutions that are currently driving voluntary dairy methane reduction in California should, by 2030, achieve the full 40 percent reduction in dairy methane sought by state regulators without the need for direct regulation."***

Continued alignment of state and federal climate-smart agricultural approaches and incentives will prove critical to deployment of additional reduction projects and to maintain progress toward 2030 as well as longer-term goals. Maintaining markets for renewable energy produced from captured dairy biomethane to ensure continued digester development and beneficial use will also be necessary. Additional research, particularly focused on deployment of effective feed additives will also prove crucial. Finally, adoption of public incentives for the integration of enteric methane solutions, such as a CARB-approved offset-compliance protocol, will be important to ensure widespread dairy sector adoption.

Introduction

California's world-leading efforts to reduce dairy methane

California took a major policy step toward reducing statewide greenhouse gas (GHG) emissions and combating climate change when Assembly Bill 32 (Nunez & Pavley, Chapter 488, Statutes of 2006) was enacted, requiring the state to reduce GHG emissions to 1990 levels by 2020. California achieved this target in 2016, four years earlier than mandated.[3] California then passed SB 32 (Pavley, Chapter 249, Statutes of 2016) in 2016, which requires the state to further reduce GHG emissions to 40 percent below 1990 levels by 2030. Also, in 2016, the state enacted SB 1383 (Lara, Chapter 395, Statutes of 2016) which seeks to reduce short-lived climate pollutants (SLCPs) including methane, by 40 percent by 2030 and required the California Air Resources Board (CARB) to implement a Short-Lived Climate Pollutant Reduction Strategy. It should be recognized that California set these aggressive SLCP targets nearly five years earlier than the 30 percent global methane pledge that has now been adopted by well over 120 countries, including the United States, following the COP26 in Glasgow in 2021.[4]

California's carrot-and-stick policy approach

SB 1383 required CARB to approve and begin implementing a short-lived climate pollutant (SLCP) strategy and established requirements for different SLCPs, including methane reduction targets. More specifically, SB 1383 requires the California dairy and livestock sectors to each reduce manure methane emissions by 40 percent below 2013 levels by 2030. SB 1383 requires CARB, in consultation with the California Department of Food and Agriculture (CDFA), to adopt regulations on or after January 1, 2024, if certain conditions are not met. SB 1383 also enables voluntary enteric emission reductions to be used to meet the dairy and livestock sectors' methane reduction goals once feed additives and other strategies are commercially available, cost effective, safe, and accepted by consumers.[5]

SB 1383 required CARB to assess the state's progress toward achieving the 40 percent manure methane reduction targets to determine whether the agency will need to develop regulations to meet the goals by the 2030 deadline. This assessment, *Analysis of Progress toward Achieving the 2030 Dairy and Livestock*

[3] See https://ww2.arb.ca.gov/our-work/topics/climate-change.
[4] COP stands for the "conference of parties" COP 26, which occurred between October 31 and November 12, 2021, in Glasgow, Scotland, was the 26th United Nations Climate Change Conference. COP 27 took place in Sharm El Sheikh, Egypt, November 6 – 18, 2022.
[5] California Health & Safety Code Section 39730.7(f)

Methane Emissions Target, was released by CARB in March 2022. CARB found that, between the methane emission reduction projects that had been funded through FY 2019–20 and decreases that are projected to result from expected livestock herd reduction, California was already on track to meet just over half of the methane emission reduction target of 9 million metric tons of carbon dioxide equivalent (MMTCO2e) with 4.6 MMTCO2e of reductions identified and accounted. CARB concluded that to achieve the target, the dairy and other livestock sectors would need to develop and implement additional projects and programs to reduce methane emissions by another 4.4 MMTCO2e. See Table 2 below for a summary of the livestock methane reductions identified by CARB to be in place by 2030.

Table 2. *Summary of CARB's Assessment of Projected Livestock Methane Reductions*

<table>
<tr><th colspan="2">Reduction Type</th><th>Number of Projects Funded through FY 2019-20</th><th>Expected Emissions Reductions Through 2030 (MMTCO$_2$e)</th></tr>
<tr><td colspan="2">Livestock Population Change thru 2022</td><td>N/A</td><td>1.3</td></tr>
<tr><td colspan="2">Livestock Population Change (2023 – 2030)</td><td>N/A</td><td>1.1</td></tr>
<tr><td rowspan="2">Anaerobic Digester</td><td>State Funded (DDRDP)</td><td>118</td><td>1.8</td></tr>
<tr><td>Privately Funded</td><td>5</td><td>0.1</td></tr>
<tr><td rowspan="2">Alternative Manure Management Practices</td><td>State Funded (AMMP)</td><td>115</td><td>0.2</td></tr>
<tr><td>Privately Funded</td><td>40</td><td>0.1</td></tr>
<tr><td colspan="2">**Total**</td><td>**278**</td><td>**4.6**</td></tr>
</table>

CARB analyzed several incentive funding scenarios post-2020 that would be needed to achieve a full (enteric and manure methane) 40 percent reduction goal by 2030. CARB's March 2022 livestock methane reduction analysis recognizes that, in addition to the finding that more than half of the requisite reductions were in place, cost-effective achievement of the remaining methane reductions will require the implementation of a variety of additional mitigation measures. A flexible and diverse array of programmatic and policy options will be necessary to achieve the 2030 target and deliver significant reductions from the livestock sector. Such an approach, as outlined in CARB's Short-Lived Climate Pollutant Reduction Strategy,[6] will "deliver significant reductions from the dairy and livestock sector while providing a variety of environmental and economic benefits."[7]

[6] CARB, Short-Lived Climate Pollutant Reduction Strategy, March 2017.
[7] CARB, *Analysis of Progress report*; p. 3.

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> *We conclude that the dairy methane reduction projects and other measures that will be implemented by 2030 are likely to meet or exceed the dairy sector methane emission reductions required by SB 1383.*

The legislature designed SB 1383 dairy and livestock methane reduction goals with a "carrot-and-stick" policy approach. This statutory structure promotes the use of a combination of rewards and potential penalties to induce a desired behavior, in this case methane reduction. SB 1383 clearly intended to prioritize the use of voluntary, incentive-based measures to achieve methane reductions before regulations would be developed and implemented, if needed. Further, SB 1383 only authorizes CARB to implement regulations to meet the 2030 dairy and livestock reduction targets after January 1, 2024, and only after key conditions are met. These considerations include the determination by CARB and CDFA that any proposed regulations are technologically and economically feasible, cost-effective, and mitigate and minimize (prevent) leakage, which occurs when milk production and resulting emissions shift out of California.[8] SB 1383 also mandates an evaluation of the achievements made by incentive-based programs.[9]

While SB 1383's incentive-based approach is working as designed, and the California dairy sector has made significant progress, the *Analysis of Progress* report's assessment is that additional methane emissions reductions must be achieved to meet the 40 percent reduction target by 2030. This paper discusses the current trends in the dairy industry, including growing worldwide demand for dairy products, increased productivity in the dairy sector, and decades of dairy farm consolidation. We review dairy sector economics, the factors that impact dairy margins, and the potential impact methane management regulations could have on California dairy competitiveness. This study reviews CARB's assessment of livestock methane reductions, including conducting a separate and more accurate assessment of dairy herd attrition trends in the state, assembling a more comprehensive and complete inventory of dairy digester projects and updating the resources available to the dairy industry for advanced manure methane reduction projects. Finally, we assess the potential impact of enteric emission reduction strategies on the dairy methane inventory. We conclude that the dairy methane reduction projects and other measures that

[8] Meredith L. Fowlie, Mar Reguant and Stephen P. Ryan, *Measuring Leakage Risk*, May 2016.
[9] CARB, *Analysis of Progress*, pp. 2-3.

will be implemented by 2030 are likely to meet or exceed the dairy sector methane emission reductions required by SB 1383.

It is clear from CARB's *Analysis of Progress* report that no single methane reduction action can achieve the targeted reductions.[10] Dairy digesters alone will not provide the methane emission reductions mandated by 2030. Instead, achieving the state's aggressive reduction goal will require a concerted approach involving methane avoidance, manure methane capture and utilization, enteric methane reduction activities and accelerated methane reductions that accompany additional dairy herd attrition in California. As a result, and regardless of the project and technology mix deployed, the most important factors for achieving the dairy sector's 2030 target are ongoing funding and support for new methane emission reduction/avoidance (alternative manure management or AMMP) projects, continued revenue streams that incentivize biogas capture and beneficial use (digesters), a commercially available, cost-effective, safe and accepted means of reducing enteric methane emissions and ongoing dairy herd efficiency.[11]

Dairy Sector Trends

Dramatic changes have transformed the U.S. dairy sector over the past several decades. Since 1950, the U.S. has produced more milk with far fewer cows while the number of dairy farms has declined significantly both in California and nationally.[12] Where milk is produced is continuing to change across the U.S. Growing national and global demand for dairy products, particularly cheese and milk powders, will likely continue these trends. Understanding these trends is critical to identifying workable policy approaches to dairy sector methane reduction, particularly if California is to avoid, as required by SB 1383, leakage to other states.

> ***It should also be noted these per capita consumption demand increases are magnified by an expanding U.S. population, which grew nearly 60 percent during this same time period.***

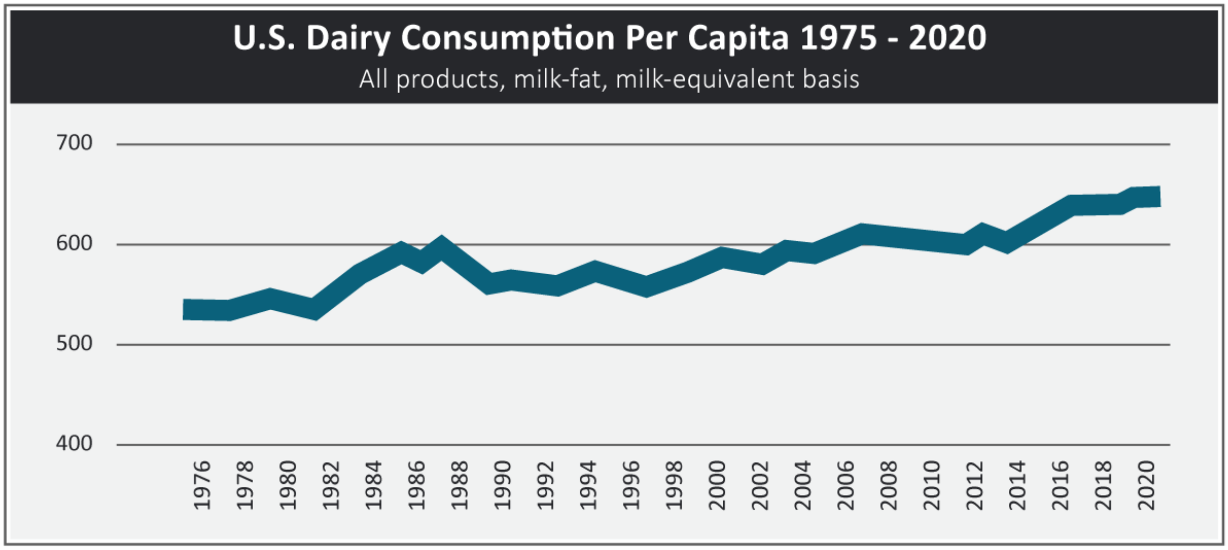
Growing demand for dairy

U.S. demand for dairy products continues to increase. Consumption patterns show that Americans now eat more dairy than they

[10] "A combination of dairy digesters, alternative manure management, enteric strategies, and dairy herd size population decreases will be needed to meet the 2030 target." CARB, *Analysis of Progress* report, p. ES-4.
[11] CARB, *Analysis of Progress*, p. ES-5.
[12] Sumner, Daniel A. 2020. "California Dairy: Resilience in a Challenging Environment." Chapter 6 in California Agriculture: Dimensions and Issues, 2nd Edition. Philip L. Martin, Rachael E. Goodhue, and Brian D. Wright, Editors. Giannini Foundation Information Series 20-01. Pp 133-162. Available at https://giannini.ucop.edu/publications/cal-ag-book/

drink, led by butter and cheese consumption, but including milk powders used as food ingredients. In 1975, the average American consumed 539 pounds of dairy foods per year. In 2020, per capita consumption had grown to 655 pounds of dairy per person, a 21.5 percent increase.[13] Per capita consumption jumped an additional 12.4 pounds per person in 2021 to 667 pounds, the highest level since 1960.[14]

Figure 2. –*Growing National Demand for Dairy Products*[15]



It should also be noted these per capita consumption demand increases are magnified by an expanding U.S. population, which grew nearly 60 percent during this same time period.[16]

[13] Corey Geiger, "Fluid milk sales fell further in 2021", Hoards Dairyman, February 24, 2022. https://hoards.com/article-31555-fluid-milk-sales-fell-further-in-2021.html#:~:text=Dairy%20product%20consumption%2C%20as%20a,to%20655%20pounds%20per%20person

[14] Record dairy product consumption for 2021 was reported in multiple locations. See International Dairy Foods Association, "U.S. Dairy Consumption Hits All-Time High in 2021 as Growing Category Evolves Toward Yogurt, Cheese, Butter." September 30, 2022, https://www.globenewswire.com/news-release/2022/09/30/2526330/0/en/U-S-Dairy-Consumption-Hits-All-Time-High-in-2021-as-Growing-Category-Evolves-Toward-Yogurt-Cheese-Butter.html#:~:text=The%20average%20American%20consumed%20667,and%20yogurt%20adding%200.7%20pounds.

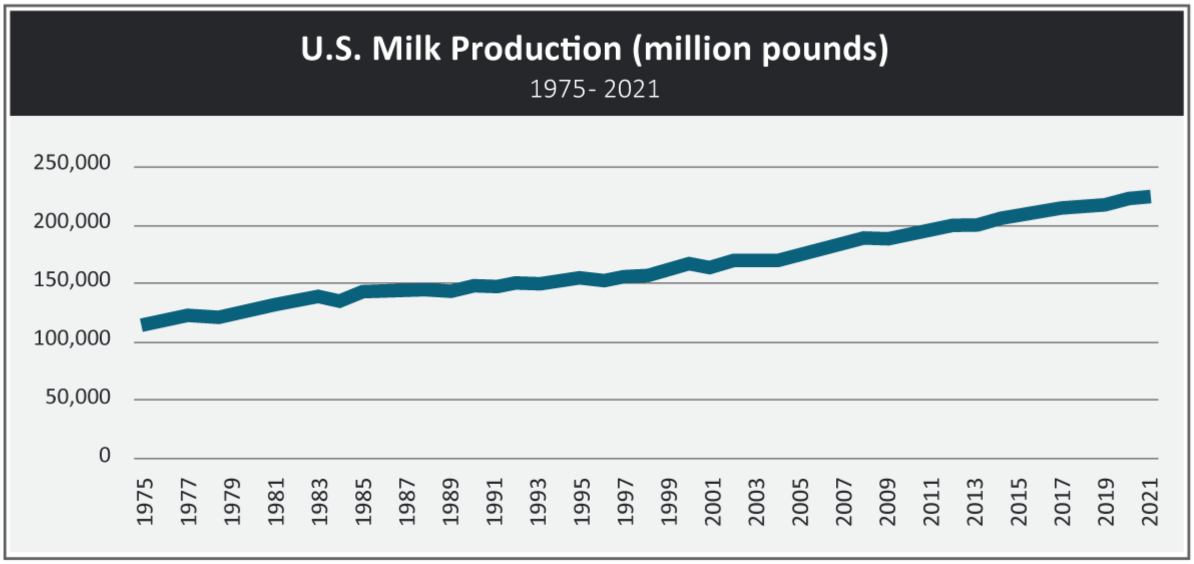
[15] Sources: USDA Economic Research Service calculations using data from USDA, National Agricultural Statistics Service; USDA, Farm Service Agency; USDA, Foreign Agricultural Service; USDA, Agricultural Marketing Service; U.S. Department of Commerce, Bureau of the Census; and California Department of Food and Agriculture. See https://www.ers.usda.gov/data-products/dairy-data/

[16] The U.S. population was 211,274,535 in 1975, growing to 335,942,003 in 2020, an increase of 124,667,468 persons, or 59%. See United State Census, Historical Population Change Data, (1910 – 2020); https://www.census.gov/data/tables/time-series/dec/popchange-data-text.html.

Increased production

To meet growing demand, U.S. milk production has grown steadily over the same period, from about 115.4 billion pounds in 1975 to more than 226.3 billion pounds in 2021.

Figure 3. *Increased U.S. Milk Production*[17]



While milk production continues to grow, where it is produced has continued to shift across the U.S. Reduced demand for fluid milk and increased demand for cheese, butter, and other dairy products with longer shelf life and lower transport costs has allowed milk production to occur further away from urban population centers. Climate change in the U.S. and elsewhere, feed price changes and limits on water availability will also likely alter areas where dairy production is concentrated in the U.S. While the top 10 milk-producing states in the U.S. did not change from 2011 to 2021, there was reshuffling and shares across states changed considerably. Table 3 highlights the changes in the top dairy-producing states between 2011 and 2021.

[17] For 1975-2000 see U.S. Department of Agriculture, National Agricultural Statistics Service, Milk Final Estimates, various years; Milk Production, Distribution, and Income, 1999 Summary, April 2000; and Milk Production, February 2001. For 2001 – 2020 see USDA, National Agricultural Statistics Service and USDA, Economic Research Service calculations, https://www.ers.usda.gov/data-products/dairy-data/.

Table 3. Shifting U.S. Milk Production

Top Ten Milk Producing States, 2011 and 2021 (billion lbs.)			
Rank	**2011**	**2021**	**Percent Change (2011 to 2021)**
1	California 41.462	California 41.864	1.0%
2	Wisconsin 26.058	Wisconsin 31.702	21.7%
3	Idaho 13,251	Idaho 16.412	23.9%
4	New York 12.838	Texas 15.599	62.8%
5	Pennsylvania 10.547	New York 15.54	21.0%
6	Texas 9.582	Michigan 11.952	41.0%
7	Minnesota 8.89	Minnesota 10.548	18.7%
8	Michigan 8.478	Pennsylvania 10.114	-4.1%
9	New Mexico 8.177	New Mexico 7.804	-4.6%
10	Washington 6.169	Washington 6.504	5.4%

Source: USDA Milk Production Reports, June 2011 and June 2021

Historically, U.S. milk production and dairy farm location was primarily driven by the demand for fluid milk to serve consumers in population centers. That changed decades ago as dairy consumption of highly perishable products, such as fluid milk, shifted to products such as butter, cheese, dry milk powders and other value-added dairy products that had longer shelf life, much higher value per unit pound and lower transport costs. This trend is exemplified by the construction of large-scale cheese plants in Clovis, New Mexico; Dalhart, Texas; and St. Johns, Michigan, to name a few. The location of future U.S. milk production growth will continue to be closely linked to regional cheese and milk powder processing capacity, including for export. New large-scale cheese processing plants are currently being built in Texas (Leprino Foods) and in Kansas (Hilmar Cheese Company). Cheese and other dairy manufacturing plants, like any food processing facility, benefit from scale and perform best when operating at or near capacity with a steady milk supply.

Regional milk production is influenced by many factors including the cost and availability of feed, energy, water and labor as well as environmental regulations and taxes. The capacity of regional policy and supply chains to accommodate large-scale dairies is also a driving factor. Rabobank researchers and dairy analysts have mapped geographic changes in cow numbers across the U.S. The analysis of changing production trends by state shows the U.S. dairy herd is migrating toward the center of the country. Given the ability to manufacture, store, and move cheese longer distances, dairy expansion is being driven to the upper Midwest and plains states.[18] The long-developing trend of manufacturing plants sourcing milk from fewer, but larger near-by dairy farms will continue moving forward.

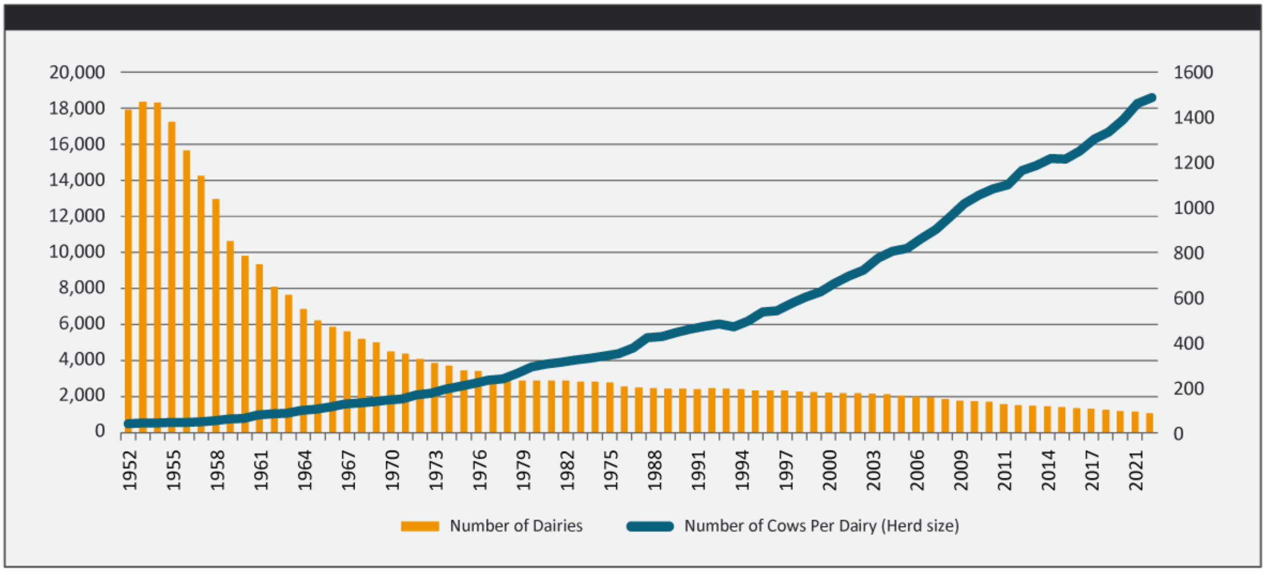
Dairy Sector Consolidation

The number of dairy farms in the U.S. has declined for decades in every major dairy state.[19] Dairy sector consolidation is not unique to California but has been occurring here at a steady rate. The dairy farm population in California peaked around 1950 at just over 18,000 farms. Since that time California experienced a 90 percent reduction in the number of dairy farms, while herd size has grown. The number of dairy farms continued to drop even as the number of cows grew rapidly between 1980 and 2008. Since 2008, the number of farms has continued to decline while the total number of cows has declined gradually from 1.88 million in 2008 to just over 1.7 million in 2021. See Figure 4 below and Table 6 on page 26 for cow population decline.

[18] See Ben Lane, "The Changing Landscape of US Dairy," RaboResearch - Food & Agribusiness, August 2019 (https://research.rabobank.com/far/en/sectors/dairy/Changing-Landscape-US-Dairy.html) and Ben Lane, "Milk Cow Migration Spurred by Processing Capacity", RaboResearch - Food & Agribusiness, September 2021 (https://research.rabobank.com/far/en/sectors/regional-food-agri/milk-cow-migration-spurred-by-processing-capacity.html)

[19] Sumner, D. A. (2014). American farms keep growing: Size, productivity, and policy. *Journal of Economic Perspectives*, 28(1), 147-66.

Figure 4. *California Dairy Farm Consolidation, 1950 - 2021*[20]



Similar trends have occurred and are accelerating in Wisconsin, the number two dairy production state. Wisconsin had 6,206 milk cow dairy herds as of September 2022, down by 61% since 2003 and 41% since 2013.[21] Even as the number of farms has declined, Wisconsin's total milk production has continued to climb, continuing a 17-year streak of annual production increases after a previous 17-year streak of gradual production declines.[22] Consolidation on remaining farms has led to larger herd sizes and growth in milk per cow. In fact, cows per herd more than doubled while, the milk production per herd in Wisconsin has more than tripled in the past 20 years as total number of milk cows held steady.

Loss of small dairies and consolidation is not an issue isolated to the two top-producing dairy states. A number of economic forces continue to drive long-term consolidation in the U.S. dairy industry. Since 2003, the U.S. has lost more than half its dairy operations, marching steadily downward, declining by more than 55 percent from 70,375 in 2003 to just 31,657 in 2020. The period from 2018 to 2020 shows larger year-over-year declines. 2020 showed the fourth largest year-over-year decline in the last 15 years and the second largest (right behind 2019) year-over-year percentage decline since 2003. There were 2,550 fewer dairy operations in the U.S. in 2020 than in 2019, when the number dropped by 3,261.[23] The recent accelerated decline reflects how, since 2014, low margins make it difficult to operate a dairy even in a high

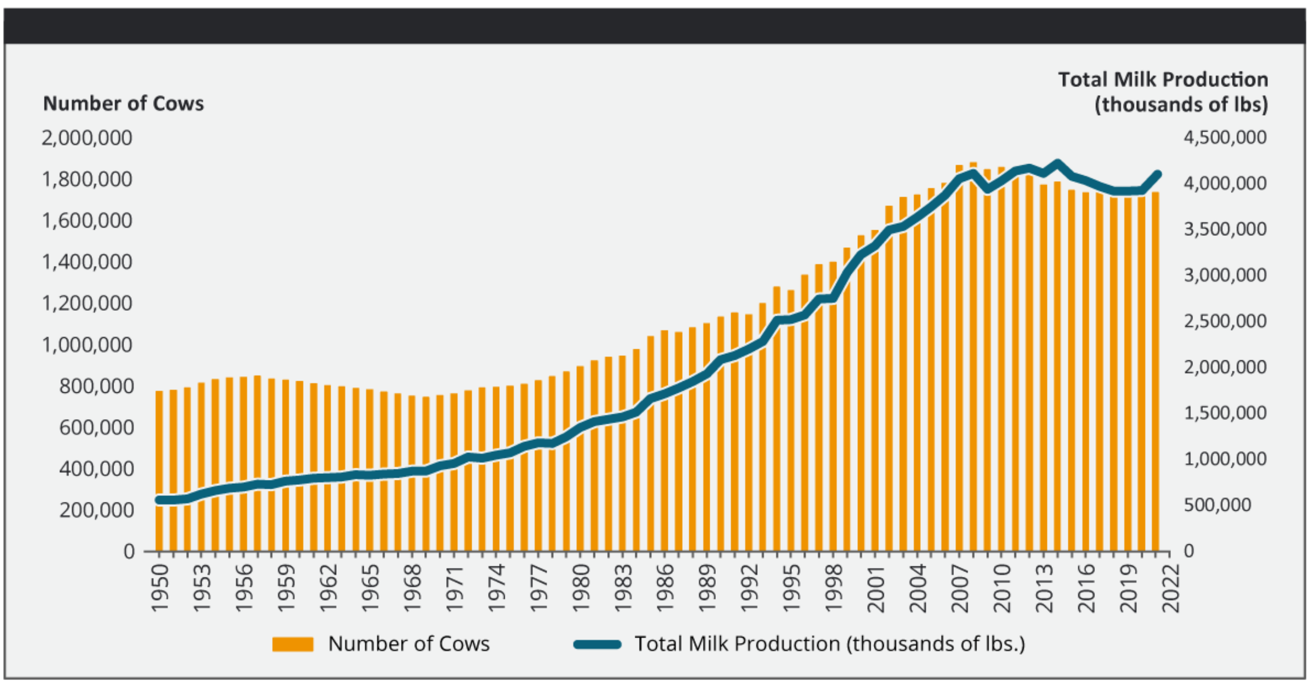
[20] 1950-2017 (for all data) - CDFA Dairy Marketing, Milk Pooling, and Milk and Dairy Foods Safety Branches; 2018-2020 (for cows and production) - USDA, National Agricultural Statistics Service
[21] See https://www.nass.usda.gov/Statistics_by_State/Wisconsin/Publications/Dairy/Historical_Data_Series /herd_brt_2004.pdf
[22] See https://quickstats.nass.usda.gov/results/01B6B68E-A9BD-323F-85B8-B39AC637741E
[23] See National Milk Producers Federation, Dairy Data Highlights, November 2021.

milk price environment. From 2014 to 2020, dairy farmers struggled with low milk prices and increased price volatility. While farmgate milk prices have increased recently, they have largely been offset by rapidly increasing feed, labor, energy, and fuel costs.[24]

California Dairy Sector Economics

The California dairy industry grew rapidly for decades to become the largest milk-producing state in the U.S. in 1993 and a significant contributor to global milk production. From 1987 to 2008 milk production grew by 130 percent as the number of milk cows grew by 73 percent. Milk production per cow also grew by one-third during this period, resulting in fewer cows needed to meet growing national and global demand. Since 2008, milk production has remained relatively stable while the number of cows has declined by 8.6 percent, a reduction that has been offset by increasing milk production per cow. California's share of national milk production has fallen from approximately 22 percent to about 19 percent during this 13-year period (2008 - 2021).[25]

Figure 5. *Recent Declining California Cow Population, 1950 – 2021*



[24] Market Intel Fb.com, February 26, 2021. According to national dairy industry groups, when dairy farms consolidate, as a rule, they consolidate into other family farms. As a result, the farms that remain are still largely family operations (NMPF, Family Farms Drive Decline, July 19, 2022)

[25] Sumner, D.A. 2020. "California Dairy: Resilience in a Challenging Environment." Chapter 6 in California Agriculture: Dimensions and Issues. P.L. Martin, R.E. Goodhue, and B.D. Wright, Eds. UC Giannini Foundation, pp.133–162. Available at: https://bit.ly/3gGfshW; also see USDA National Agricultural Statistics Service (NASS) Quickstats.

California is part of a national and global market for dairy products. Only about 10 - 15 percent of California milk solids are used for fluid products restricted to local markets by transportation cost. The rest of California milk competes in national markets for soft and frozen products and national and global markets for products such as cheese, butter, and dry milk powders.[26] Dry milk powders are key ingredients in literally thousands of food products produced around the globe. High transport costs from farms to processing plants leads to milk being processed near where it is produced. As a result, local processing efficiencies are crucial for the economic health of the farms in the milk production industry. If local processors face high costs, they must offer lower prices to farms to be competitive in national and global markets.

Feed costs account for more than half of total farm milk production costs but vary from year to year with feed crop prices. Replacement heifers and fixed capital costs together account for another approximately 20 percent of milk production costs. Hired labor accounts for about 12 percent of costs, which are escalating due to labor shortages, wage increases, and overtime payments (Table 5). California dairy operations generally face higher feed, transportation, energy and fuel, labor, and water costs, as well as significantly higher costs associated with regulatory compliance than dairy operations in other states.[27]

California dairy operations generally face higher feed, transportation, energy and fuel, labor, and water costs, as well as significantly higher costs associated with regulatory compliance than dairy operations in other states.

California dairies work hard to remain competitive with milk producers in other states and countries, benefiting from relatively abundant, low-cost agricultural byproduct feeds, scale economies, innovation,

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[26] Ibid.

[27] Numerous studies document the higher costs that California farmers face due to increased regulation. These include Lynn Hamilton, "Comparing California's Cost of Regulation to Other States: A Case Study Approach for Agriculture," California Institute for the Study of Specialty Crops, CISSC Project Number 49958, October 17, 2006; Lynn Hamilton and Michael McCullough, "A Decade of Change: A Case Study of Regulatory Compliance Costs in the Produce Industry," Cal Poly, San Luis Obispo, December 15, 2018; Lynn Hamilton and Michael McCullough, " Assessing the Economic Impacts of Agricultural Equipment Emission Reduction Strategies on the Agricultural Economy in the San Joaquin Valley: Phase Two, 2018 Costs," Cal Poly, San Luis Obispo, June 16, 2021; In 2010 the annual cost of regulation of California farms was estimated at $2.2 billion, or about 6.5 percent of the total market value of the state's agricultural production. See Hurley, S., R. Thompson, C. Dicus, L. Berger and J. Noel, Analysis of the Regulatory Effects on California Specialty Crops: An Examination of Various Issues Impacting Selected Forest Products, Tree Fruit, Nut and Vegetable Crop Industries, report for California Institute for the Study of Specialty Crops, 2006 (www.cissc.calpoly.edu/research).

and quality management. One skill California dairies are constantly honing is how to cope effectively with regulation, which tends to be more demanding in California than in other leading dairy states. The challenges of SB 1383 are a perfect example – no other state in the U.S. is requiring its dairy sector to reduce methane emissions.

Farm consolidation is expected to continue, and without such consolidation California's dairy farmers would likely find themselves at a competitive disadvantage with dairy farms that are continuing to consolidate in other states. The bottom line is any factors that increase the cost of milk production in California will erode the competitive position of the state's milk producers in national and global markets. Cost increases would likely trigger a decline in milk production in California, and the loss of important local and state economic contributions from dairies, especially in the San Joaquin Valley.[28]

Methane emissions and manure handling costs

The discussion of costs, revenues, competitiveness, and economic prospects of the California dairy sector outlined above included no explicit consideration of manure handling costs. These costs have not historically been accounted for in data collection since they were not large enough, on average, to be captured in surveys. However, the importance of manure handling and management costs is increasing with advancing water quality regulation and potential climate policy requirements. Direct regulation of dairy manure management practices and the reduction or elimination of incentives have the potential to raise associated costs substantially. All technically feasible methods to reduce methane emissions are costly. This includes shifts to pasture-based herds, compost-bedded pack barns, use of mechanical solids-liquids manure separation, and the integration of manure digesters in dairy operations.[29] Added annual costs to reduce methane ranges from a few hundred dollars per cow to over $2,500 per cow for digester systems. These added costs, unless

> ***These added costs, unless offset by grants and other incentives, would add significantly to overall production costs and significantly erode California's competitive position.***

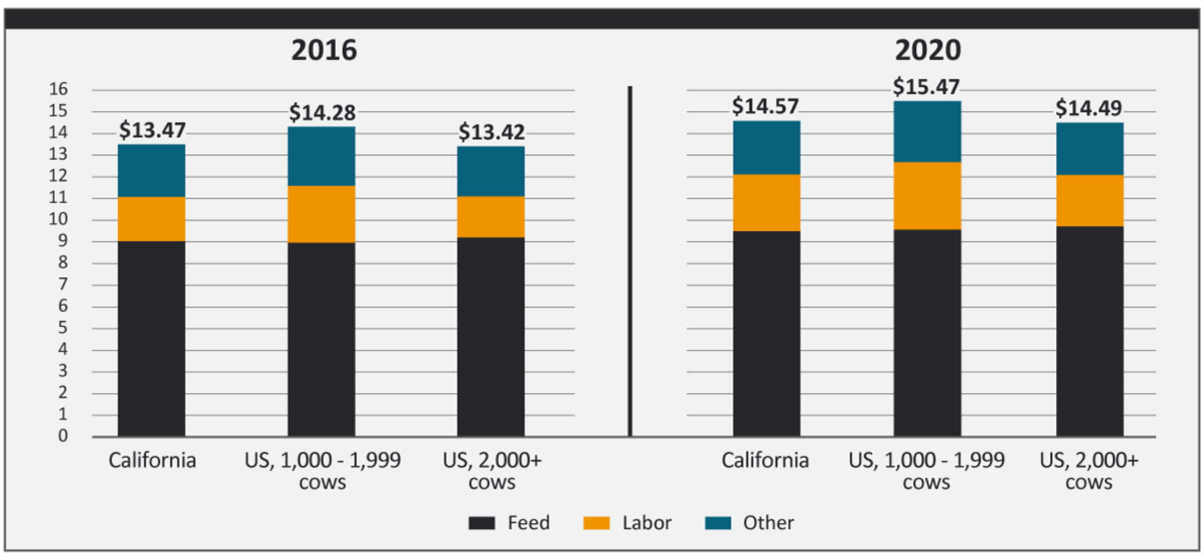
[28] Matthews, W.A. and D.A. Sumner. 2019. "Contributions of the California Dairy Industry to the California Economy in 2018." A Report for the California Milk Advisory Board. University of California Agricultural Issues Center. Available at: https://bit.ly/3nwm8RL.

[29] Mullinax, D., D Meyer and D. Sumner. 2020. "Small Dairy Climate Change Research: An economic evaluation of strategies for methane emission reduction effectiveness and appropriateness in small and large California dairies." Final Report: Contract No. 17-0750-000-SG. Prepared for the California Department of Food & Agriculture, California Dairy Research Foundation, Chapter 4.2.

offset by grants and other incentives, would add significantly to overall production costs and significantly erode California's competitive position.

It should also be noted that expanding pasture-based dairy farming as a share of California milk production, beyond its current less than 5 percent share, would raise milk production costs substantially. Further, the high cost and limited availability of irrigation water as well as the impacts of climate change in coastal regions of California, which have historically accommodated pasture operations, are further limiting factors. Compelling local dairy farmers to pay for manure methane reduction through direct regulation or shift to pasture-based farming would significantly increase costs, adding to California's already high operating cost environment.

Figure 6. *Farm Cost of Milk Production, California and National Comparisons ($ per hundredweight)*[30]



> ***The economic forces are clear. Costly manure handling mandates for California dairy farms to reduce methane, or penalties such as a carbon tax, would lead to milk production shifting to regions not facing such methane reduction (manure management) costs, resulting in dairy-related methane emissions shifting to other states and countries (the "leakage" conundrum).***

[30] Source: Based on data from Economic Research Service, USDA. Prices of dairy of feed rose remarkably from 2020 to 2021 in California and the rest of the U.S., but relationships between California and the U.S. as a whole did not change.

Meeting the Call

Based on cost comparisons in Figure 6 and recognizing the increasingly competitive nature of national and global dairy markets, any increased cost of milk production would put California dairies at a significant competitive disadvantage relevant to efficient producers outside the state. The economic forces are clear. Costly manure handling mandates for California dairy farms to reduce methane, or penalties such as a carbon tax, would lead to milk production shifting to regions not facing such methane reduction (manure management) costs, resulting in dairy-related methane emissions shifting to other states and countries (the "leakage" conundrum).

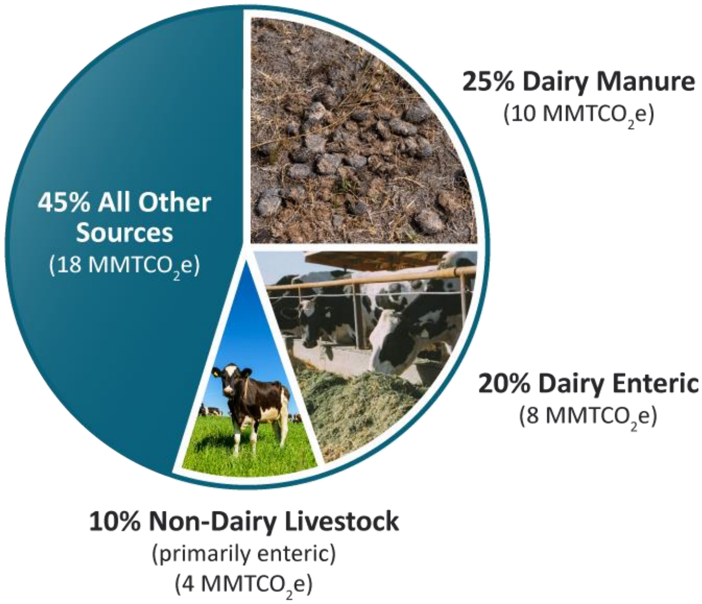
California policy makers have recognized these economic and environmental realities. California greenhouse gas policies, including SB 1383, acknowledge leakage as a critical concern due to the global nature of climate emissions. California policy makers clearly developed the incentive-based approach to dairy and livestock methane to avoid simply shifting dairy methane emissions from California to other regulatory jurisdictions, which do not perceive climate protection as a policy priority. Policy makers recognize that forcing California dairy operations to other regions does not result in a net reduction of global methane emissions. California legislators and regulators, like their federal counterparts, are appropriately utilizing incentive-based approaches to achieve desired dairy and livestock methane reductions. The Biden Administration recently championed passage of the Federal Inflation Reduction Act (IRA) that includes more than $20 billion in direct incentives for climate-smart agriculture, including dairy operations.

> ***There is in some parts of the public, the environmental community and others, there is interest in pushing a regulatory approach towards agriculture. I don't think it will work....I think a far better approach is one based on voluntary incentives, that creates opportunities for folks to come to the table that understands the diversity of agriculture.***
>
> **Robert Bonnie**, Undersecretary of Agriculture for Farm Production and Conservation USDA Dairy Defined Podcast March 7, 2022

Dairy Methane Emissions

In 2013, methane accounted for 40 MMTCO2e in California.[31] This equates to approximately 9 percent of the state's total GHG emissions (CARB).

Figure 7. *2013 California Methane Emissions by Source*[32]



As shown in Figure 7, the dairy and livestock sectors are significant sources of methane emissions in California, producing approximately 22 MMTCO2e combined or 55 percent of statewide methane emissions. Roughly 80 percent (18 MMTCO2e) of those emissions were from manure management and enteric fermentation at nearly 1,500 dairies throughout the state.[33] Today, between 1,100 to 1,200 dairies house just over 1.7 million milking cows and another roughly 1.5 million animals in replacement stock.[34] Non-dairy livestock, primarily beef cattle, account for the remaining 4 MMTCO2e.

Despite clear legal limitations in SB 1383,[35] CARB continues to seek a full 40 percent reduction in all dairy and other livestock for both manure and enteric methane emissions, or approximately a combined 9 MMTCO2e annually.[36] This level of reduction cannot be achieved solely by manure methane reductions. Because enteric methane accounts for roughly 12 MMTCO2e of the total 22 MMTC02e from the dairy and

[31] (CARB – 100-year GWD from IPCC AR4)
[32] CARB, *Analysis of Progress* report, p. 6.
[33] It is important to note that the number of California dairies in the 2013, the SB 1383 baseline year, was higher than it is today, According to CDFA data, there were 1,496 dairies operating in California in 2013.
[34] CARB Dairy livestock inventory. These animals are generally between age zero and two years. Some of the heifers in the replacement stock spend some of this period outside of California.
[35] Legislative Counsel Opinion prepared for the Honorable Jim Wood, "Short-Lived Climate Pollutants: Dairy and Livestock Industry: Methane Emissions Reductions - #1915885, November 2019.
[36] To be precise, 40% of 22 MMTCO2e = 8.8 MMTCO2e.

livestock sectors, cost-effective enteric methane reduction strategies will need to be developed and widely implemented in both the dairy and beef cattle sectors to achieve the 9 MMTCO2e reduction target sought by CARB. Roughly 7.2 MMTCO2e of the targeted 9 MMTCO2e reductions will need to come from the dairy sector alone, with the other 1.8 MMTCO2e coming from the beef cattle and other livestock sectors.[37]

In enacting SB 1383, the legislature directed CARB, in consultation with the CDFA to seek 40 percent reduction in manure methane from each of the dairy and other livestock sectors, as follows:

> ***Section 39730.7, (b)(1) – The state board, in consultation with the department, shall adopt regulations to reduce methane emissions from livestock manure management operations <u>and</u> dairy manure management operations, consistent with this section and the strategy by up to 40 percent below the dairy sector's <u>and</u> livestock sector's 2013 levels by 2030.***[38] **(Emphasis added)**

Analysis of dairy sector progress to date

The California dairy sector has made tremendous progress toward achieving the 7.2 MMTCO2e annual reduction sought by CARB. The recently finalized *Analysis of Progress* report [39] documents this momentum. CARB's assessment summarizes substantial investments in manure management strategies through 2020, documents livestock herd-size reductions in California between 2012 and 2017, and projects livestock herd attrition out to 2030. CARB concludes that, through dairy digester development, herd attrition and including small reductions from alternative manure management projects livestock methane will decrease by a total of roughly 4.6 MMTCO2e by 2030. These reductions were reflected in Table 2 on page 7.

Virtually all of the reductions identified in the CARB analysis are expected to occur in the state's dairy industry. All of the projects funded through CDFA's Alternative Manure Management Program (AMMP) and digester reductions are dairy related, as are the herd attrition reductions. In fact, CARB's *Analysis of Progress* report assumes that, while the state's dairy sector will be contracting, California's beef and livestock sector will be growing.[40] CARB's analysis assumes, disproportionately, that the burden of reducing both the dairy and livestock sector's methane emissions will fall almost entirely on the California dairy

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[37] 18 MMT CO2e X 0.4 (40%) = 7.2 MMT CO 2e

[38] California Health & Safety Code Section 39730.7(f)

[39] CARB, *Analysis of Progress*, Ibid.

[40] ARB's herd size trends are derived from USDA's 2017 Census of Agriculture. Whereas the California dairy herd shrank between 2012 and 2017, 1,815,655 to 1,750,329 cows, the beef herd increased from 583,594 to 682,372 animals. See 2017 Census of Agriculture, United States, Summary and State Data, Volume 1, Geographic Area Series, Part 51, AC-17-A-51, Issued April 2019, p. 395.

sector. As a result, CARB's analysis appears to suggest the dairy sector will need to achieve considerably greater emissions reductions from additional manure management projects and proven enteric mitigation strategies or other measures to compensate for anticipated emissions growth in the California beef sector.

Continued Progress - 2022-2030

The present paper builds on CARB's analysis to date and identifies how the dairy sector's targeted methane reductions (7.2 MMTCO2e) will be achieved. This paper generally concurs with CARB that targeted reductions will be achieved through continued implementation of manure management methane reduction projects as well as wide-scale adoption of enteric methane strategies and continued dairy herd size reduction. However, we strongly believe that CARB may have underestimated ongoing dairy herd attrition in California, and our research shows that there are approximately double the number of dairy digesters CARB recognized currently in operation and/or under development in California. Furthermore, significant additional state and federal funds for dairy methane reduction programs have been made available since CARB completed its analysis. The next several sections will provide a discussion of how CARB's targeted dairy sector reductions will be achieved through a combination of the following:

- Ongoing dairy herd size attrition and increased production efficiency
- Continued manure methane avoidance
- Continued manure methane capture and utilization
- Implementation of enteric strategies

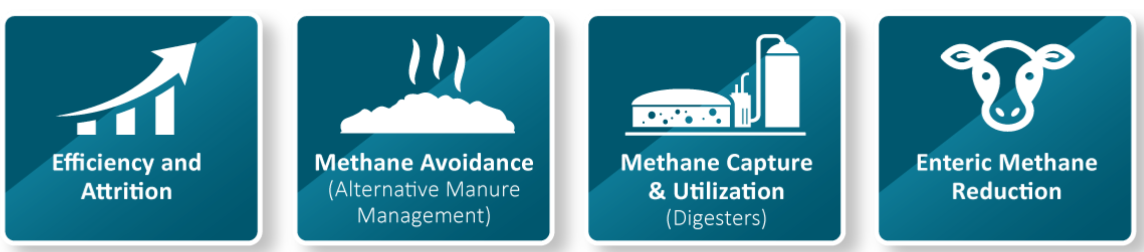


Figure 8: *Four Primary Strategies to Reduce Dairy Methane*

Each of these four components of a comprehensive dairy methane reduction strategy are generally recognized by CARB, the California Department of Food and Agriculture (CDFA), the U.S. Department of Agriculture (USDA), the U.S. Environmental Protection Agency (USEPA), and the Intergovernmental Panel on Climate Change (IPCC).[41] Equally important, they are recognized by California's dairy sector as necessary

[41] See United Nations Environment Programme and Climate and Clean Air Coalition (2021). Global Methane Assessment: Benefits and Costs of Mitigating Methane Emissions. Nairobi: United Nations Environment

to achieve the targeted reductions.[42] California's dairy sector also highlights the need for further research and innovation as an important strategy moving forward. What all parties recognize is that there is no silver bullet to reducing dairy and livestock methane, and that any successful strategy will require an "all-of-the-above" comprehensive strategy.

Herd Attrition

As discussed earlier, California's dairy sector underwent a period of tremendous growth from 1970 to 2008. Since 2008, however, total herd size has been reduced from 1.88 million milk cows to just over 1.7 million milk cows in 2021 (See Table 6 on page 26). Overall herd size is projected to continue to gradually contract in California, while production is expected to be relatively stable due to continued increases in milk production per cow. For California, the decrease of the state's dairy herd poses two important questions: what has been the impact on the dairy sector's methane emissions caused by herd attrition and what will be the rate of herd decline between now and 2030?

Enteric and manure emissions both correlate with cattle population. More animals result in higher methane emissions. The opposite is also true: as dairy cattle populations continue to contract consistent with recent trends, dairy methane will continue to decrease. If observed attrition trends accelerate, then the resulting rate of methane emission reductions will also be greater.

CARB currently estimates that livestock herd reduction trends observed between 2008 and 2017 will continue, resulting in a one-half percent (0. 5%) annual reduction in cattle between 2018 and 2030.[43] However, CARB's analysis mixes **growth** in the beef cattle population with clear **reduction** in the dairy herd. This methodology presents multiple analytic shortcomings:

1. Mischaracterization of methane reduction trends in the dairy industry by combining California dairy sector herd decreases with beef sector animal increases;
2. Underestimation of past and future dairy sector methane reductions in the state's inventory;
3. Failure to consider that California dairy attrition will likely occur at a faster rate going forward, given the array of significant and growing challenges facing dairy farming in California.

Programme at p. 16;

[42] Dairy Cares Comments on the California Air Resources Board's March 29, 2022, Workshop on Methane, Dairies and Livestock, and Renewable Natural Gas in California, submitted April 12, 2022.

[43] CARB, *Analysis of Progress*, pp. 10 – 11.

California's beef and dairy sectors are separate and distinct in their feed patterns, manure handling practices and economic drivers. The manure from beef cattle is typically widely dispersed rather than managed in flush systems. California beef cattle also rely to a far greater extent on forage diets consisting of grasses from pasture and grazing lands unsuitable for crop production, resulting in significant enteric methane production. Demand and supply of beef is driven by the price and availability of beef products in national and global markets which are distinct from the dairy sector and lead to significant fluctuation in the number of beef cattle in the state, which is a relatively small part of the US beef industry.

As a result, it is critical California regulators and policymakers consider and mange methane and other GHG emissions from these distinct sectors separately as required by SB 1383. For example, nearly all of the methane from beef cattle production are enteric emissions due to major differences in how beef cattle are raised and manure is managed. Reducing these emissions will largely be dependent on emerging enteric strategies placing even greater importance on the development of these solutions.

Table 4 below, which replicates the Table provided by CARB, helps to explain why separating the dairy herd from other livestock is so important to understanding the impact of herd attrition on the state's dairy methane emissions. CARB's approach took livestock (beef and dairy) data from the U.S. Ag Census between 2012 and 2017, derived an average attrition rate, and applied this factor to the entire period through 2030. This table shows that CARB derived its estimate of the annual livestock population attrition rate by mixing inconsistent and opposite trends in the beef and dairy herd.

Table 4: *CARB's "California cattle population statistics and changes in cattle populations with corresponding percentage of change based on 2012 and 2017 USDA Ag Census reports. Parentheses indicate negative numbers."* [44]

Animal Category	Population by Ag Census Year		Population Change	Population Change %
	2012	2017		
Dairy Cows	1,816,655	1,750,329	(66,326)	(3.65)
Support Stock	2,917,282	2,752,892	(164,390)	(5.64)
Beef Cows	583,594	682,372	98,778	16.9
Total Cattle	**5,370,531**	**5,185.593**	**(184,938)**	**(3.44)**

[44] This data is the actual table provided by CARB staff. There are two major errors herein. First, the 2012 figure for dairy cow population was entered incorrectly. The actual number reported by USDA was 1,815,655. Second, the total for 2012 is added incorrectly; the total should be 5,317,531. These errors produced incorrect Total Cattle Population Change and Population Change % figures. When adding the correct USDA data, the total livestock population change for the period should be -132,950, or a total of -2.5%.

As this paper documents, the assumption that the beef and dairy trends are the same fails to recognize the real and fundamental differences between the two distinct sectors. Thus, it was methodologically inappropriate for CARB to mix the two when assessing the herd attrition trends and rates. A more accurate assessment of the dairy herd attrition rate should be derived by deleting the beef animal population from the herd size trend assessment. This approach is reflected in Table 5. When using the exact same data and approach as CARB staff used in the *Analysis of Progress* report, the only difference being removing beef livestock from the assessment, the result is an annual attrition rate nearly double that reported by CARB.

"When using the exact same data and approach as CARB staff used in the Analysis of Progress report, the only difference being removing beef livestock from the assessment, the result is an annual attrition rate nearly double that reported by CARB."

Table 5: *Adjusted Dairy Herd Attrition Rate, 2012 - 2017*

Animal Category	Population by Ag Census Year		Population Change	Population Change (%)	Annual % Rate
	2012	2017			
Dairy Cows	1,815,655	1,750,329	-65,326	-3.60%	-0.72%
Support Stock	2,917,282	2,752,892	-164,390	-5.64%	-1.13%
Total Cattle	**4,734,949**	**4,505,238**	**-229,711**	**-4.85%**	**-0.97%**

One challenge presented by the USDA data is that "Support Stock" figures are not differentiated between the beef and dairy industries. Generally, beef cattle have to be replaced at a higher rate than dairy cows, as a lactating dairy cow can be productive for 4 - 5 years or longer. However, even if the support stock is evenly distributed between beef and dairy cattle, it does not fundamentally change the resulting trends.

Another step that can be taken to validate the higher herd attrition rate for the California dairy sector is to also analyze CDFA dairy cattle population data. Prior to 2018, when California joined the Federal Milk Marketing Order, the CDFA conducted its own surveys of both the number of California dairy farms and total herd size.[45] Once the state transitioned to the Federal system on Nov. 1, 2018, CDFA ceased collecting this data. While CDFA dairy herd figures are slightly different than the census data provided by USDA, they confirm similar dairy herd attrition trends.

[45] "California dairy industry transitions to FMMO", Farm Progress, September 21, 2018; https://www.farmprogress.com/dairy/california-dairy-industry-transitions-fmmo.

Table 6. *Dairy Herd Attrition in California, 2008 - 2017*[46]

Year	Number of Cows	Change from Prior Year	% Change from Prior Year
2008	1,882,746	14,138	
2009	1,847,660	-35,086	-1.86%
2010	1,858,028	10,368	0.56%
2011	1,836,112	-21,916	-1.18%
2012	1,819,760	-16,352	-0.89%
2013	1,773,890	-45,870	-2.52%
2014	1,789,440	15,550	0.88%
2015	1,747,770	-41,670	-2.33%
2016	1,738,090	-9,680	-0.55%
2017	1,735,350	-2,740	-0.16%
Average Herd Reduction/Year, 2008 - 2017			**(13,325.80)**
Average % Reduction/Year, 2008 - 2017			**-0.90%**
Average Herd Reduction/Year, 2012 - 2017			**(16,882.00)**
Average % Reduction/Year, 2012 - 2017			**-0.94%**

Source: CDFA

Thus, when appropriately assessing just dairy herd data, regardless of the source, the conclusion is the same – California dairy herd population is decreasing at a faster annual rate than that attributed by CARB in the *Analysis of Progress* report. Whether looking at just the lactating cow population alone or adding in the support animal population, the rate of decline in the California dairy sector is between -0.75% to -1% a year. This is the minimal attrition factor range that CARB should use to estimate future dairy sector methane reduction trends.

CARB's *Analysis of Progress* report estimates that the total dairy sector methane emissions (both from manure and enteric sources) was 18 MMTCO2e in 2013. Using USDA data for 2012 and a range of herd attrition rates that include both CARB's and those presented in Tables 4 and 5 above, we can estimate the 2013 dairy herd population at between 1,798,043 to 1,806,577 animals. Dividing 18 million MMTCO2e by the estimated number of dairy cows in 2013 provides the total methane emissions rate per animal in 2013, or roughly 10 MTCO2e/cow. In addition, CDFA data supplied a specific figure for the 2013 dairy cow

[46] Source: CDFA Dairy Marketing, Milk Pooling, and Milk and Dairy Foods Safety Branches

population of 1,773,890, which divided in to the 2013 dairy methane inventory yields a per animal methane emissions rate of 10.15 MTCO2e/cow. See Table 7 for a summary.

Table 7. *Estimates of 2013 Dairy Cow Methane Emissions Rate*

	No. of Dairy Cows, 2012	% Reduction in Herd	No. of Dairy Cows, 2013	Avg. Methane Emissions, Cow/Yr. (MTCO2e)
USDA	1,815,655	0.5%	1,806,577	9.964
	1,815,655	0.720%	1,802,582	9.986
	1,815,655	0.97%	1,798,043	10.011
CDFA (2013)	1,773,890	0.5%	1,773,850	10.147

Using this simple and straightforward method, we can easily estimate the methane emission reductions associated with the loss of each dairy milk cow, which equates to roughly 10 metric tons per year. This enables the development of a clearer estimate of the total methane reductions from likely dairy herd attrition between 2013 and 2030 using more appropriate, dairy-herd -only, derived annual attrition rates.

Using USDA data, the California dairy herd lost 65,326 animals between 2012 and 2017. Using the per cow methane production factors from Table 7, this results in an estimated annual methane emission reduction of between 650,882 and 662,875 MTCO2e from California dairy herd attrition in the five-year period. These estimates are summarized in Table 8 below.

Table 8. *Estimated Methane Reductions, Dairy Herd Attrition, 2013-2017*

CH4 Emission Rate/Cow (MTCO2e)	Total CH4 Reduction, 2013 - 2017
9.964	650,882
9.989	652,521
9.924	648,276
10.147	662,875

If the rate of herd attrition and associated methane reductions were to remain constant over the period of 2013 thru 2030, California should expect to realize a methane emission reduction over the 18-year period of between 2.34 and 2.39 MMTCO2e. However, there is evidence to suggest the pace of dairy herd attrition will increase in this decade. There are multiple factors that are likely to accelerate recent population attrition trends including, but not limited to, the following:

- Continuing drought, increasing aridification, and resulting cutbacks in surface water deliveries
- Increasing water scarcity and widespread land fallowing due to implementation of the Sustainable Groundwater Management Act (SGMA) and limits on groundwater pumping
- Continued wage increases and labor shortages
- Significant and rapidly rising energy, fuel, and feed costs
- Increased regulation, particularly, increasing waste discharge requirements expected for Central Valley dairies

The observed annual dairy herd attrition rate between 2012 – 2017 was between 0.72% and 0.97%. This paper conservatively assumes that the lower end of this observed range held constant through 2021 and that a 1% herd reduction rate occurs from 2022 thru 2030. Using these herd attrition factors, rates that more accurately reflect prior dairy industry trends, the estimate for total dairy sector methane reductions between 2013 and 2030 range between 2.61 and 2.66 $MMTCO_2e$. These estimates, which are higher than those provided by CARB in *Analysis of Progress*, are summarized in Table 9.[47]

Table 9. *Estimate of Dairy Sector Methane Reduction from Herd Attrition, 2013 - 2030*

CH4 Emission Rate/Cow ($MTCO_2e$)	Total CH4 Reduction, 2013 - 2017	Total CH4 Reduction, 2018 - 2030	Total CH4 Reduction, 2013 - 2030
9.964	650,882	1,962,113	2,612,995
9.989	652,521	1,967,056	2,619,577
9.924	648,276	1,954,257	2,602,533
10.147	662,875	1,998,268	2,661,144

This methodology can also be used to project possible dairy sector methane emission reduction scenarios from higher attrition rates. Assuming the same methodology described above used to provide the projections in Table 9, but now using 2022 – 2030 herd average annual attrition rates of 1.25% and 1.5%, the range of possible methane reduction for California herd attrition between 2013 and 2030 increases to between 2.96 and 3.36 $MMTCO_2e$. These scenarios are summarized in Tables 10 and 11 below.

[47] See CARB, *Analysis of Progress* Report, pp. 10 -12.

Table 10. *Estimate of Dairy Sector Methane Reduction from Herd Attrition, 2013 – 2030, Using 1.25% Average Annual Attrition Rate, 2022 - 2030*

CH4 Emission Rate/Cow (MTCO2e)	Total CH4 Reduction, 2013 – 2017	Total CH4 Reduction, 2018 – 2030	Total CH4 Reduction, 2013 – 2030
9.964	650,882	2,310,341	2,961,223
9.989	652,521	2,316,161	2,968,682
9.924	648,276	2,301,091	2,949,367
10.147	662,875	2,352,913	3,015,789

Table 11. *Estimate of Dairy Sector Methane Reduction from Herd Attrition, 2013 – 2030, Using 1.5% Average Annual Attrition Rate, 2022 - 2030*

CH4 Emission Rate/Cow (MTCO2e)	Total CH4 Reduction, 2013 - 2017	Total CH4 Reduction, 2018 - 2030	Total CH4 Reduction, 2013 - 2030
9.964	650,882	2,651,588	3,302,470
9.989	652,521	2,658,267	3,310,788
9.924	648,276	2,640,971	3,289,247
10.147	662,875	2,700,447	3,363,323

Using the same USDA data as was analyzed by CARB, but only assessing the trends in the California dairy sector, this paper concludes that the methane emission reductions that are attributable to dairy herd attrition should be higher than what CARB has projected. In addition, given the likely scenarios that the rate of dairy herd attrition could accelerate in the remaining years before 2030, it is easy to envision scenarios where the methane reductions will be even greater. Accelerating rates of attrition need to be factored into any future discussions about dairy methane mitigation regulation.

Manure Management

Dairy manure methane emissions can be reduced through two primary methods: 1) methane avoidance and, 2) methane capture and utilization. Manure methane can be avoided by changing manure management practices on dairy operations. These projects can provide climate benefits through avoided methane production and environmental co-benefits such as soil health, water quality improvement and conservation, reduction of synthetic fertilizer usage and improvement of nutrient management, as well as groundwater protection.[48] Alternative manure management practices can take many forms, including but not limited to the following:

- Liquid – solid manure separation systems
- Conversion of flush/lagoon systems to scrape or vacuum with subsequent solar drying or composting of manure instead of anaerobic storage
- Utilization of compost-bedded pack barns
- Conversion to pasture-based systems[49]

The CDFA's AMMP has invested significant dollars in projects through 2020, funding some 115 projects. Table 12 below shows the average methane emissions reductions and cost effectiveness of these alternative manure management projects. According to the table, solid liquid separation projects have the highest per project average methane emissions reductions and the lowest implementation costs among the practices.

Table 12. *CDFA AMMP Performance* [49]

Estimated Methane Emissions Reduction Potential and Cost Effectiveness of AMMP Projects (Through 2022)			
AMMP Practices	Reduction per Project ($MTCO_2e$)	Cost-effectiveness (S/$MTCO_2e$)	
		State Investment	Total Investment
Compost Bedded Pack Barn	1,880	$73	$91
Flush-to-Scrape Conversion	1,420	$78	$88
Solid-Liquid Separation	2,120	$54	$58

Additional funding for CDFA manure management programs was made available in the 2021-2022 and the 2022-2023 state budgets with a priority for AMMP. The last two budget cycles have made a total of $108 million available for CDFA's dairy methane reduction programs. CDFA recently awarded the first $37.65 million of this funding to a total of 41 AMMP and Dairy Digester Research and Development Program (DDRDP) projects. An additional $68 million is available in the current 2022-2023 California fiscal year and

[48] CARB, *Analysis of Progress,* p. ES-3.
[49] While conversion of flush systems to pasture-based systems will lead to a reduction in manure methane it likely results in an increase in enteric emissions due to reduced productivity and an increase in diet based enteric emissions.
[49] CARB, *Analysis of Progress*, p. 17.

will be awarded in 2023. These new investments will further increase the methane emissions reductions that will result from manure management practices.

California's dairy sector, in coordination with CDFA, was also recently awarded up to $85 million by the USDA under the Partnerships for Climate-Smart Commodities. The funding will leverage an additional $40 to $45 million in matching state funds and estimated private capital investments of up to $180 million, or a total of over $300 million in new investment.

According to the funding application, the funding will be utilized for innovative, multi-benefit on-farm advanced manure management projects that avoid methane creation while also addressing other key environmental concerns, such as nutrient capture and water quality protection. Project funding will be implemented by the CDFA, as part of their existing dairy methane reduction programs. Practices eligible for funding are expected to include but not be limited to vermifiltration, composting, algae raceways, advanced solid-liquid separation, and evaporative liquid waste processing systems.

Additionally, the federal Inflation Reduction ACT (IRA) also provides $20 billion over the next several years for climate-smart agricultural programs and projects, including $8.45 billion in new funding for the Environmental Quality Incentives Program (EQIP). The IRA also provides $4.95 billion in new funding for the Regional Conservation Partnership Program, which targets methane reduction.

These significant additional funds will greatly expand investments in methane avoidance and capture projects, resulting in significant additional dairy methane reduction in California.

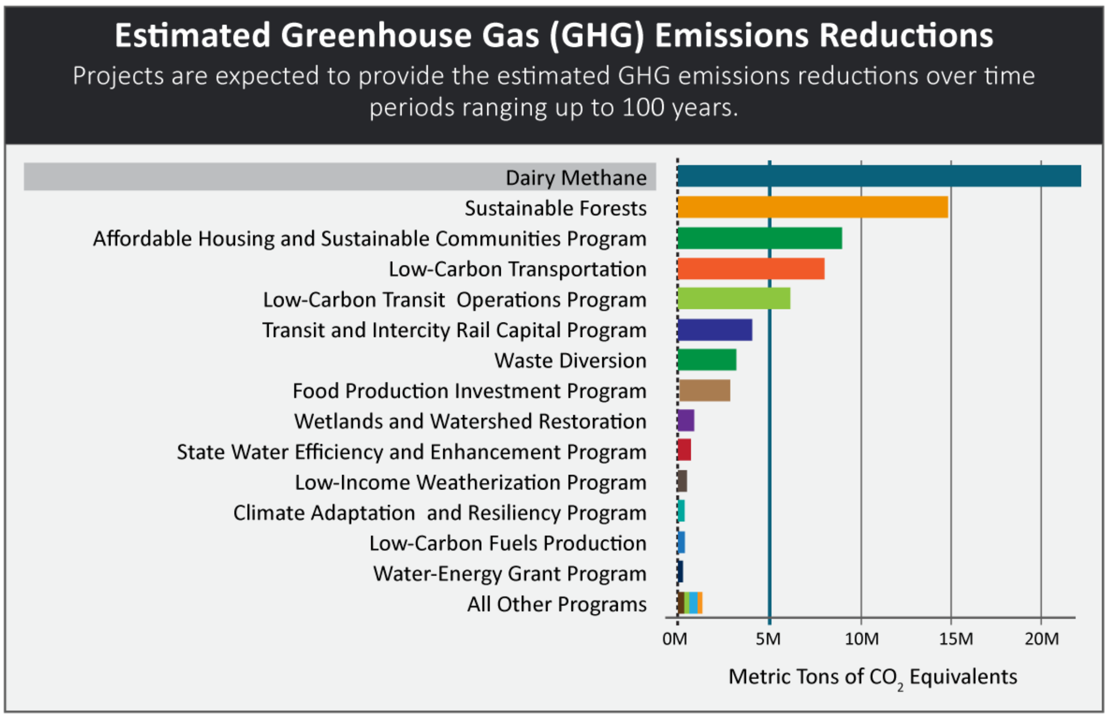
Methane Capture and Utilization

Dairy digesters are widely recognized as one of the most efficient and effective ways to reduce dairy manure methane emissions. AgSTAR is a collaborative program sponsored by the U.S. Environmental Protection Agency (EPA) and USDA that promotes the use of biogas recovery systems (digesters) to reduce methane emissions from livestock waste. According to the U.S. EPA, anaerobic digestion has many environmental and economic benefits, including producing renewable energy and reducing greenhouse gas emissions, and is underutilized as a manure

> ***According to the U.S. EPA, anaerobic digestion has many environmental and economic benefits, including producing renewable energy and reducing greenhouse gas emissions, and is underutilized as a manure treatment option.***

treatment option.[50] Development of dairy digesters has been the primary driver of GHG (methane) emission reductions in the California dairy sector, accounting for approximately 90 percent of all manure methane reductions to date, and more than half (54 percent) of total expected dairy sector emission reductions by 2030.[51] The state's annual California Climate Investments report regularly credits dairy digesters as being the most cost-effective expenditure of the state's Cap & Trade GHG reduction resources. Importantly, as shown in the chart below, dairy methane reduction is also providing more total GHG reductions than any other program funded by the state.

Figure 9: *Effectiveness of Dairy Methane Reduction in California*[52]



Source: *California Climate Investments Data Dashboard*

Prior to the enactment of SB 1383, about 15 dairy digesters were operating in California. Expanded state incentives designed to offset the high capital cost of digester installation has fueled broader interest and adoption of digesters. In addition to grants provided for capital costs by CDFA's DDRDP, other critical incentive programs have enabled projects to monetize the reductions and provide ongoing revenue

[50] AgSTAR website
[51] See CARB, *Analysis of Progress* report, p. 12.
[52] From the California Climate Investments website; https://www.caclimateinvestments.ca.gov/cci-data-dashboard.

streams that enable financing and development of these expensive methane reduction facilities. These programs include:

- Bioenergy Market Adjusting Tariff (BioMAT)
- Cap-and-Trade Offset Program
- Low Carbon Fuel Standard (LCFS) Program
- Federal Renewable Fuel Standard (RFS)
- California Public Utilities Commission (CPUC) Pipeline Interconnection Incentive Program
- Renewable Natural Gas Procurement (SB 1440)

These incentive programs have been and will continue to be critical to achieving California's ambitious dairy methane reductions and overall climate goals. In the absence of these incentive programs, dairies would not be able to afford to build and operate anaerobic digestion facilities on their farms and achieve the associated significant methane emission reductions. As CARB has recognized, while dairy digesters offer significant and cost-effective methane emission reductions, without large-scale public incentives, the rate of adoption would likely decrease greatly.[53] U.S. EPA identifies development of dependable markets that increase project revenue and reduce project costs as the most effective ways to address economic barriers to digester development.[54]

"As CARB has recognized, while dairy digesters offer significant and cost-effective methane emission reductions, without large-scale public incentives, the rate of adoption would likely decrease."

CARB's *Analysis of Progress* report does assess the methane reduction benefits of the state's move to dairy digesters.[55] However, CARB's inventory of dairy digester projects that are currently in operation and under development substantially undercounts the actual number of projects that are being undertaken in the Golden State, and thus dramatically underestimates the full potential volume of methane emission reductions that will occur from this foundational strategy by 2030.

[53] "While dairy digesters offer significant and cost-effective methane emissions reductions, without large-scale public incentives, the rate of adoption would likely decrease greatly." CARB, *Analysis of Progress* report, p. 18.
[54] AgSTAR website
[55] See CARB, Analysis of Progress report, pp. 9, 12 – 15.

More complete inventories compiled by leading industry observers and validated in this analysis indicate that, by June 1, 2022, there more than 225 dairy digesters either in operation in California or being actively developed by an increasingly expanding dairy digester development sector. This represents 116 more projects than accounted for by CARB in their "Analysis of Progress" report, or virtually double the number of dairy digester projects. If each of these additional projects achieves the same annual methane emission reduction as the average dairy digester project funded by the DDRDP (17,817 MTCO2e annually), then CARB has significantly underestimated the expected methane emissions reductions from California dairy digesters by approximately 2 MMTCO2e annually.

The inventory of California dairy digester projects and the estimate above may not adequately document the total number of dairy digester projects being pursued by dairy farmers and digester developers in the state. CDFA recently published a list of 27 more dairy digester projects that applied for new DDRDP funding in 2022 and awarded $18.71 million in grants to 14 of these applicants.[56] In addition, recent conversations and public statements from dairy digester developers indicate that there may be as many as 25 additional dairy digester projects not accounted for by either CARB or the digester inventory discussed above.[57] Thus, even the projection of additional methane reductions from anerobic digestion anticipated herein may underestimate the 2030 total.

Enteric Methane Reduction

Enteric methane from the dairy and other livestock sectors is a significant source of greenhouse gas emissions in the U.S. and California, accounting for 12 MMTCO2e annually in the state, a full 30 percent of statewide methane emissions (CARB). Dairy cattle account for 8 MMTCO2e of enteric methane and the remaining 4 MMTCO2e is from beef cattle and other ruminant livestock.

[56] See https://www.cdfa.ca.gov/oefi/ddrdp/. "CDFA awarded 14 projects for the 2022 DDRDP solicitation, totaling $18.71 in grant funding. The list of awarded projects is available. Applications were accepted between March 10 and May 9, 2022. CDFA received 27 applications requesting $35.38 million in grant funds."

[57] See "Aemetis Biogas Closes $25 million USDA Guaranteed Project Financing with Greater Commercial Lending for Dairy Farm Biogas Digesters and Pipeline to Produce Renewable Natural Gas," Press release from October 6, 2022.

> *These feed additives show great promise, long-term effectiveness, and no adverse impacts on animal or human health.*

Potential strategies to reduce emissions from the digestion process include diet modifications, feed additives, feed efficiency improvements, mechanical devices and selective breeding of low methane producing animals. California dairy farms are already leaders in highly nutritious cow diets and feed efficiency. While selective breeding practices are also common in California, they require a relatively long time to achieve significant emissions reductions. As a result, feed additives offer the greatest potential for short-term sector-wide methane reductions due to their ability to deliver considerable methane emissions reductions shortly after adoption.[58] Unlike manure management strategies, utilization of feed additives could be implemented at existing operations with minimal need to modify facility design or operations and without significant upfront capital requirements. While feed additives hold considerable methane mitigation potential, lack of proven, commercially available and cost-effective additives remains a limiting factor.

A recently conducted meta-analysis[59] examined 98 enteric methane mitigation options from a comprehensive data set of treatment means from 425 peer-reviewed studies published between 1962 and 2018. The authors found that most of the options (63 out of 98 or 64%) were not successful in mitigating enteric methane.[60] The authors ultimately found that only five options reduced enteric methane production and emissions intensity without negatively affecting milk production, and only three options reduced emissions intensity while increasing animal productivity (milk production).

While a comprehensive discussion of enteric methane mitigation options is beyond the scope of this paper, several feed additives are expected to become commercially available in the next several years, which could be used to reduce enteric methane emissions from California's dairy herd. These feed additives show

[58] Honan, M., X. Feng, J. Tricarico and E. Kebreab. 2022. "Feed additives as a strategic approach to reduce enteric methane production in cattle: modes of action, effectiveness, and safety." Animal Production Science, 62 (14): 1303–1317.
[59] Arndt, C., A. N. Hristov, W. J. Price, S. C. McClelland, A. M. Pelaez, S. F. Cueva, J. Oh, J. Dijkstra, A. Bannink, A. R. Bayat, L. A. Crompton, M. A. Eugene, D. Enahoro, E. Kebreab, M. Kreuzer, M. McGeek, C. Martin, C. J. Newbold, C. K. Reynolds, A. Schwarmm, K. J. Shingfield, J. B. Venemann, D. R. Yanez-Ruiz, and Z. Yu. 2022. Full adoption of the most effective strategies to mitigate methane emissions by ruminants can help meet the 1.5°C target by 2030 but not 2050. PNAS 119:20 e2111294119. DOI: https://doi.org/10.1073/pnas.2111294119.
[60] Ibid.

great promise, long-term effectiveness, and no adverse impacts on animal or human health. Each of these is discussed below:

3-NOP (Bovaer)

The most well-studied potential feed additive for reducing methane, 3-Nitrooxypropanol (3-NOP), is expected to become commercially available in the U.S. by 2024 - 2026. There is a significant body of evidence to support the effectiveness of 3-NOP in reducing enteric methane emissions by approximately 30 percent.[61] 3-NOP is currently undergoing long-term trials and FDA approval. 3-NOP's manufacturer, DSM, recently signed a licensing agreement with U.S.-based Elanco Animal Health to manufacture and market the product in the U.S. Bovaer is approved for use in Brazil, Chile, Australia, Israel, and the European Union.

Mootral Ruminant

This pelleted, natural product made from garlic powder and citrus extract has shown methane mitigation potential in both in-vivo and in-vitro studies of around 20 percent.[62] Additional research is planned on both beef cattle and dairy animals at UC Davis. Since Mootral is made primarily from readily available ingredients, particularly in California, it can likely be scaled up quickly. The supplement can be easily integrated into the feed chain, depending on the needs of different farming systems.

Agolin Ruminant

This essential oil mix has shown methane reduction potential of around 8 to 10 percent in in-vivo studies. Agolin is commercially available and being used in California to increase feed efficiency. Agolin is Generally Recognized as Safe (GRAS) by FDA, however, additional studies on its effectiveness will need to be conducted to verify its enteric mitigation potential.

Seaweed and Algae

Seaweed and algae have also demonstrated the ability to mitigate methane emissions. Seaweeds have highly variable chemical composition, depending on the species, time of collection, and growth environment. Some macro algae contain specific bioactive components that inhibit activity of methane-forming microbes in the rumen. Although there are many species of seaweed, research has shown that two

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[61] Alemu, et al, "3-Nitrooxypropanol Decreased Enteric Methane Production from Growing Beef Cattle in a Commercial Feedlot: Implications for Sustainable Beef Cattle Production," Frontiers in Animal Science, Feb. 16, 2021, https://www.frontiersin.org/articles/10.3389/fanim.2021.641590/full.

[62] See Roque, B.M., H. J Van Lingen, H. Vrancken, and E. Kebreab. 2019. Effect of Mootral—a garlic- and citrus-extract-based feed additive—on enteric methane emissions in feedlot cattle. Translational Animal Science, 3(4): 1383–1388; and

red seaweed species, *Asparagopis taxiformis* and *A. armata* have specific qualities that help inhibit enteric methane production when fed to cattle.[63] For example, research conducted on a commercial dairy in California documented a reduction of 52 percent when *Asparagopsis taxiformis* was added to cattle feed.[64] CDFA recently approved the use of Brominata, trade name for a red seaweed product produced by Blue Ocean Barns, as a "digestive aid" enabling additional commercial testing on farms in the state.

To better illuminate the potential methane mitigation benefits of feed additives, the following table has been developed to illustrate various levels of effectiveness at different dairy herd penetration scenarios. In developing projections for enteric methane reduction, this paper takes into consideration information on feed additives that are in the process of becoming commercially available or are under development. The primary products discussed above provide an effectiveness range from 10 percent to greater than 50 percent. Scenarios considered in this paper assume adoption rates ranging from 50 percent to 80 percent for dairy milk cows only. For purposes of this exercise, a constant 1.7 million milk cows producing milk in California was assumed. CARB asserts that feed additives can be incorporated into existing operations to potentially achieve significant methane emission reductions at little to no additional capital costs.[65] CARB estimates that 20 percent of the state's 40 MMTCO2e of methane (about 8 million MTCO2e) comes from dairy enteric emissions. Using 8 MMTCO2e as the baseline, the range of potential enteric methane reductions at various rates of adoption (from 50 to 80 percent dairy milk herd penetration) and effectiveness (ranging from 10 to 50 percent effective), would result in potential enteric emission reductions of between 400,000 to 3.2 million MTCO2e. However, for this analysis a more conservative approach is adopted. Whereas ARB's methodology attributes a higher level of CO2e annually to each animal's enteric emissions, other sources put this figure at roughly 3 MT/yr.[66] Using this lower figure for each dairy cow's enteric emissions yields a highly conservative estimate of the reductions that are likely to result from the implementation of feed additives to reduce enteric emissions.

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[63] See Breanna M. Roque, Marielena Venegas, Robert D. Kinley, Rocky de Nys, Toni L. Duarte, Xiang Yang, and Ermias Kebreab, "Red seaweed (Asparagopsis taxiformis) supplementation reduces enteric methane by over 80 percent in beef steers," Plos One, 16(3), March 17, 2021.

[64] Grace van Deelen, "Feeding Cows Seaweed Reduces Their Methane Emissions, but California Farms Are a Long Way from Scaling Up the Practice, Inside Climate News, June 14, 2022; Audrey Schmitz, "Red seaweed supplement achieves 52 percent methane reduction," Progressive Dairy, February 7, 2022.

[65] CARB, *Analysis of Progress*, p. 22.

[66] C. Alan Rotz, "Symposium review: Modeling greenhouse gas emissions from dairy farms," Journal of Dairy Science, Volume 101, No. 7, 2018, p. 6677.

Table 13: Enteric Methane Reduction Potential

Dairy Herd Penetration *Projections of Enteric Methane Emission Reduction Strategies at Various Dairy Sector Penetration Scenarios (in MTCO2e/yr.)*				
Reduction Effectiveness of Feed Additives	Heard Penetration			
	50%	60%	70%	80%
10%	255,000	306,000	357,000	408,000
20%	510,000	612,000	714,000	816,000
30%	765,000	918,000	1,071,000	1,224,000
40%	1,020,000	1,224,000	1,428,000	1,672,000
50%	1,275,000	1,530,000	1,785,000	2,040,000

Assumes 1.7 million milk cows producing 3 MTCO2e annually

As Table 13 demonstrates, widescale adoption of feed additives has the potential to provide substantial enteric methane reduction in the California dairy sector. For purposes of this analysis, those reductions range from 255,000 MTCO2e/yr. methane emissions assuming a feed additive with 10 percent reduction effectiveness and 50 percent herd penetration to 2,040,000 MTCO2e/yr. reductions with 50 percent reduction effectiveness and 80 percent herd penetration.

Enteric Implementation

Mitigation of enteric methane emissions is a major focus of farmer-led voluntary efforts by the dairy sector in California, the U.S., and globally. Enteric reductions are necessary to meet environmental stewardship goals announced publicly in the U.S. Dairy Stewardship Commitment.[67] Global food companies such as Nestlé, Starbucks, and Unilever have announced similar goals to accelerate climate change action and reduce greenhouse gas emissions across their supply chain.[68] Widescale adoption of enteric feed additives and sustained mitigation of enteric methane production becomes a valuable tool for dairy value chains to meet their greenhouse gas reduction goals.

[67] US Dairy Stewardship Commitment. https://www.usdairy.com/getattachment/f2bf0217-3f4b-4b04-9500-45c85c61bc82/u-s-dairy-stewardship-commitment.pdf?lang=en-US&ext=.pdf

[68] For Nestle see https://www.nestle.com/sustainability/climate-change/zero-environmental-impact; For Starbucks see https://stories.starbucks.com/stories/2020/starbucks-furthers-commitment-to-sustainability-goals-by-joining-transform-to-net-zero/; For Unilever see https://www.unilever.com/planet-and-society/climate-action/partnering-with-suppliers-to-deliver-net-zero/.

Research on nutrition and management based enteric methane mitigation options must continue and expand to support identification and adoption of mitigation options and better understand their consequences on animal health, well-being, productivity, and product quality,[69] including the following:

- Better delivery mechanisms, especially for grazing animals
- Long-term effects on animal health, well-being, and reproduction
- Adaptation by ruminal microbiome in the animal
- Milk compositions, shelf life, sensory attributes (taste and smell), and consumer acceptance

Two organizations based in the United States, the Foundation for Food and Agriculture Research (FFAR) and the Dairy Research Institute have recently launched the Greener Cattle Initiative (GCI) to fund projects which identify, develop, and validate new and existing mitigation options for enteric methane.[70] The GCI is expected to award up to $5 million in grant funding over its initial five-year period to help advance the voluntary greenhouse gas reduction goals established by both the U.S. and global dairy sectors.[71] The Global Methane Hub was established to raise funds for methane mitigation and is expected to raise $100M for agriculture related mitigation.

California Investing Heavily in Dairy Methane Research

California policymakers are also investing heavily in dairy methane reduction research. Over the past two state budget cycles, California has committed $20 million to CDFA for additional research into methane reduction efforts, especially enteric emission reduction strategies and opportunities. Five million dollars was appropriated in the last two budget cycles (2021-2022 and 2022-2023) for general research on dairy methane reduction efforts, including cost effectiveness of various strategies, environmental benefits, and emission reduction verification. An additional $10 million was provided to CDFA in the current fiscal year for enteric feed additive research and demonstration projects. This funding is critical to identifying workable enteric emission reduction strategies to achieve the state's aggressive dairy and livestock targets.

[69] Tricarico, J.M., Y. de Haas, A.N. Hristov, E. Kebreab, T. Kurt, F. Mitloehner and D. Pitta. 2022. Symposium review: Development of a funding program to support research on enteric methane mitigation from ruminants. J. Dairy Sci., in press.
[70] See https://foundationfar.org/consortia/greener-cattle-initiative/.
[71] Tricarico et al, 2022.

Other Strategies

Several other approaches to reduce dairy methane have been offered by stakeholders including dramatic increases in pasture-based agro-ecological farming and direct regulation of the dairy sector. Both are discussed below.

Agro-Ecological Farming

Some parties have suggested the state should consider increased conversion to agro-ecological pasture-based farming. USDA data documents that the productivity of organic farming methods is typically lower than that of comparable "conventional farms," including dairy farms. As a result, to produce the same amount of milk as conventional farms, organic dairies typically require more cows and, as a result, more land, water, and other resources.[72]

> ***Mandating conversion to pasture-based systems will likely lead to greater pressures on scarce resources while causing potentially increased overall methane emissions, and a larger overall environmental footprint for the sector.***

While conversion of some farms to organic dairy farming may continue, the economic pressures on organic production are at least as strong as on conventional dairies, with organic demand still tied primarily to declining beverage fluid milk sales.[73] Moreover, other U.S. regions have proven to be relatively low-cost producers of organic milk products for national markets.[74] Conversion to pasture-based organic dairy farming is a costly and challenging endeavor and consumer demand for more expensive organic milk has been under pressure from plant-based substitute beverages.[75] An influx of additional organic milk production without a commensurate increase in demand would further harm already weak organic milk markets. Equally important, conversion to pasture-based agro-ecological systems will lead to increased land requirements due to lower stocking rates (1 cow per 1-2 acres) and increased water requirements if organic dairies rely on irrigated pastures. While both are limiting factors in California, additional irrigation water is not available to support such a significant expansion in pasture-based farming without prohibitively high cost.

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[72] D.A. Sumner, D.R. Messner, and P. Valdes-Donoso (2019). Organic Dairy: Economic Opportunities and Challenges with a Focus on California. *Organic Farmer, 3*(2): 10-14. https://aic.ucdavis.edu/wp-content/uploads/2019/07/OrganicFarmer_June-July-2019-Dan-SumnerNOADS.pdf

[73] Ibid.

[74] Murray Carpenter, "Milk Companies Look West, Pressuring Northeast Dairy Farmers," New York Times, January 10, 2022. https://www.nytimes.com/2022/01/05/business/organic-dairy-farms-new-england.html.

[75] USDA, ERS, 2009

Switching to pasture-based operations with lower milk per cow volumes will also require more cows to produce the same amount of milk[76] and lead to increased enteric methane production from diets high in roughage. The limited number of applications for alternative manure management projects seeking to implement pasture-based operations also appears to confirm low interest in and the economic infeasibility of conversion to pasture-based milk production. The conclusion is that, in order to meet current demand for milk products, mandating conversion to pasture-based systems will likely lead to greater pressures on scarce resources while causing potentially increased overall methane emissions, and a larger overall environmental footprint for the sector. Conversion to organic dairy farms will also lead to higher costs for California consumers.

Direct Regulation and Leakage

Some parties have also suggested that CARB should implement direct regulation of the dairy sector. While SB 1383 clearly limits this option to after January 1, 2024, careful consideration and experience suggests it will likely result in significant methane leakage, and thus exacerbate global climate change. California policymakers recognize the impacts of emissions leakage, and SB 1383 specifically recognizes that likelihood and requires CARB to consider its implications before adopting any further regulation.

As discussed previously, carbon leakage occurs when there is an increase in GHG emissions in one jurisdiction as a result of an emissions reduction requirement in another. In the dairy sector this would occur if dairy operations facing regulation in California were replaced by operations in another state or country with limited or no regulation. The resulting increases in production and emissions in the non-regulated market would result in a net zero global reduction in GHG emissions and could possibly increase greenhouse gas emissions due to the shift in production to a state that doesn't value climate protection and limit emissions. California is a highly efficient producing region. Shifting production to a less efficient region would also result in a net-increase in global methane emissions. It must also be recognized that the potential for emission leakage in the dairy sector is increased as a result of strong and growing national and global demand for dairy products.

Given increases in U.S. and global demand for dairy products, aggressive mandatory regulation of California's dairy operations would predictively lead to significant methane leakage. This would result when

[76] Lawrence D. Muller discusses the lower milk production per cow of grazing operations vs. confinement in "Pasture-Based Systems for Dairy Cows in the United States,' Penn State Extension, May 9, 2016. https://extension.psu.edu/pasture-based-systems-for-dairy-cows-in-the-united-states

> *Given increases in U.S. and global demand for dairy products, aggressive mandatory regulation of California's dairy operations would predictively lead to significant methane leakage…As a result, leakage would likely result in a net global increase in GHG emissions.*

dairy production in California decreases due to aggressive regulation, and production shifts to another state or global jurisdiction where methane emissions are likely higher due to lax regulation. As a result, leakage would likely result in a net global increase in GHG emissions.

Achieving Climate Neutrality

Unlike other sources of greenhouse gas emissions such as those associated with fossil fuel use, milk production systems are part of the biological carbon cycle and can function as a sink for greenhouse gases, thereby contributing to reverting climate change, due to methane's substantially shorter atmospheric lifetime than carbon dioxide and nitrous oxide.[77]

Methane is continuously removed from the atmosphere by hydroxyl oxidation. As a result, its atmospheric warming effects depend on the rate of emissions increase or decrease over the last 20 years rather than the total cumulative amount emitted over that period.[78] The consequence of this behavior is that mitigation of dairy methane production at rates greater than its natural rate of oxidation reduces total atmospheric methane concentrations, effectively reverting climate change affects.[79] In other words, reducing dairy methane production has an effect on atmospheric warming similar to removing a fixed amount of carbon dioxide from the atmosphere by sequestering it in soil or plant matter (for example, planting trees).[80]

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[77] Le Quéré et al., 2018

[78] Allen, M. R.; Shine, K.P.; Fuglestvedt, J.S.; Millar, R.J.; Cain, M.; Frame, D.J.; Macey, A. H. (2018). A solution to the misrepresentations of CO2-equivalent emissions of short-lived climate pollutants under ambitious mitigation. npj Clim. Atmos. Sci. 1, 1–8.

[79] John Michael Lynch, Michelle Cain, Raymond T Pierrehumbert, Myles Allen, "Demonstrating GWP*: a means of reporting warming-equivalent emissions that captures the contrasting impacts of short- and long-lived climate pollutants", Environmental Research Letters IOP Publishing 15:4 (2020) 044023

[80] S.E. Place, C.J. McCabe and F.M. Mitloehner, "Symposium Review: Defining a pathway to climate neutrality for US dairy cattle production," Journal of Dairy Science, Vol. 105, Issue 10, P. 8558 – 8568, October 1, 2022.

Cain et al., 2019 found that sustained annual reductions of just 0.3% in methane production are sufficient to reduce atmospheric warming from methane over time.[81] As a result, reduction of dairy sector methane of greater than 0.3%, such as what is currently occurring in California will offset the atmospheric warming effects of carbon dioxide and nitrous oxide emissions from milk production resulting in overall climate neutrality, or no additional warming. This ability to revert climate altering impacts by reducing dairy methane production places milk production systems in a unique position to convert climate impact to societal benefit.[82]

Conclusion

California's dairy sector is well positioned to achieve a 40 percent reduction in methane by 2030. These reductions will be best achieved through continued implementation of California's existing incentive-based approach, including methane avoidance, methane capture and utilization, implementation of emerging enteric solutions, along with continued milk production efficiency gains, as the number of dairy cows in California continues to decline.

California's current methane avoidance program, CDFA's AMMP provides important methane reduction opportunities, particularly for smaller dairies where methane capture and utilization technologies are less suited. Continued funding of this program is critical, as is expansion to include advanced manure management projects, such as vermifiltration, that can provide greater methane reduction benefits.

Continued implementation of dairy digesters in California is also critical. Dairy digesters represent the most proven, efficient, and cost-effective opportunity to significantly reduce dairy methane emissions. Continued funding of the CDFA's DDRDP remains crucial. CDFA's program is the most successful climate program funded by the state, providing significant carbon reductions (more than any other program to date) in a highly cost-effective manner. Maintaining economically viable markets and revenue streams for the recovery and beneficial use of renewable energy from digesters is also critical for long-term sustainability of projects.

[81] Cain, M. et al. Improved calculation of warming-equivalent emissions for short lived climate pollutants. npj Clim. Atmos. Sci. 2, 1–7 (2019).
[82] Naranjo A.; Johnson, A.; Rossow, H.; and Kebreab, E. (2019). Greenhouse gas, water, and land footprint per unit of production of the California dairy industry over 50 years. Dairy Sci. 103:3760–3773

Meeting the Call

Enteric emission reduction opportunities are increasingly emerging and are likely to be commercially available in the near term. Several promising feed additives are completing testing and being approved for commercial use. As these products become available, broad implementation across the dairy sector can provide significant additional reductions. Development of a CARB-approved offset compliance protocol will be an important tool to both quantify, verify, and help offset the costs of feeding these products.

After a period of rapid growth, California's largest-in-the-nation dairy sector is experiencing a period of relatively constant milk production. Gradually declining cow numbers will likely continue, driven by increasing costs, water scarcity, and increasing regulation, particularly more aggressive water quality requirements. Fewer cows in California will mean reduced methane emissions in the state. Policy makers should keep a close eye on milk production declines in California, especially as consumer demand for dairy products continues to increase across the country and the globe. Emissions leakage is a very real threat to the objectives of California climate policy, as evidenced by rapid expansion of dairies in the midwestern and plains states. Emission leakage through increased production in other countries where production is far less efficient will also lead to increasing global methane emissions.

Table 14 summarizes the progress and projections for the California dairy sector's methane reductions toward the 40 percent target by 2030. As the table documents, the dairy sector is on pace to meet and likely exceed the sector's 7.2 MMTCO2e methane reduction target.

Projected Dairy Sector Methane Reductions		
Reduction Type	**CARB Identified Livestock Emission Reductions Through 2030 (MMTCO2e)**	**Expected Dairy Emission Reductions Through 2030 (MMTCO2e)**
Herd Reduction	2.4	2.61 – 3.3
Anaerobic Digestion	1.9	4.15
Alternative Manure Management Practices	0.3	0.6 - 1.1
Enteric Emission Reduction Strategies	0	0.25 – 2.04
Total	**4.6**	**7.61 – 10.59**

To build on this momentum, additional research, particularly into enteric emission strategies will also be crucial. California must continue to invest in the development of new strategies to reduce livestock methane emissions and develop and implement policies to enable widespread adoption by the industry.

Meeting the Call

California's dairy methane reduction efforts are widely recognized as nationally- and world-leading. California's incentive-based approach is now being adopted by the Biden Administration (USDA) and the U.S. Congress, which recently appropriated an additional $20 billion to USDA for climate-smart agricultural practices and billions more for renewable energy incentives.[83]

> ***"California's dairy sector is well positioned to achieve a 40 percent reduction in methane by 2030. These reductions will be best achieved through continued implementation of California's existing incentive-based approach…"***

California regulators and policy makers should remain diligent and ensure the tremendous state investment continues to pay in methane reduction dividends. Dairy sector emission reductions are critical to achieving the state's SLCP and broader GHG climate goals moving forward.

[83] USDA, "Vilsack Highlights USDA's Climate Initiatives and Investments at COP27", Press Release No. 0240.22. See https://www.usda.gov/media/press-releases/2022/11/12/vilsack-highlights-usdas-climate-initiatives-and-investments-cop27.