March 1, 2024

Liane M. Randolph, Chair
Dr. Steven Cliff, Executive Officer
Katherine Estabrook, Clerk of the Board
California Air Resources Board

Karen Ross, Secretary
California Department of Food and Agriculture

Via email

Re: Petition for Rulemaking to Regulate Methane and Other Air Pollutants from California Livestock

Dear Chair Randolph, Secretary Ross, and Dr. Cliff:

We were very pleased to see the press release announcing that "California launches methane-cutting effort with subnational governments at COP28." In this letter we suggest multiple ways for the Air Resources Board and the California Department of Food and Agriculture to make rapid progress on this mission.

With this letter we are formally petitioning CARB to commence the rulemaking required by SB 1383. This action by the Board will put California in the lead of the newly-formed Subnational Methane Action Coalition announced at COP 28 as well as other U.S. states.

Methane is a potent driver of atmospheric heating. Due to its powerful near-term effects, control of this gas is essential to California, the US, and indeed the world meeting our climate. Yet inexplicably, California has given a regulatory pass to the single biggest anthropogenic methane source: livestock.

Sources of methane (in MMT CO_2e per CARB inventory for 2020 using GWP 20) include

- Oil and gas extraction and delivery: 18.64. CARB regulates those emissions.
- Landfills: 20.24. CARB regulates those emissions.
- Livestock — 62.75. *These emissions are completely unregulated.*

There are proven methods of reducing manure-generated methane—anaerobic digesters and a variety of specific ways of handling manure that reduce anaerobic conditions outside a digester

or in absence of one. However, these methods are being adopted by far too few dairy farmers in order to meet the legislatively mandated 40 percent reduction by 2030 and a much greater reduction by 2045. Seven synergistic actions can ensure that California meets the goals established in SB 1383:

1. Require that all dairies adopt *some* effective approach to mitigating methane.
2. Adopt a system of measuring emissions on all farms in order to determine overall methane emissions more accurately and to facilitate regulations.
3. Establish stable funding resources to help dairies exceed the minimum standard, using digesters and other measures that are otherwise beyond the capacity of farmers to finance.
4. Over the next twenty years, greatly reduce or eliminate wet or lagoon style management and replace it with “dry” management and affiliated methods.
5. Regulate the aspects of dairy greenhouse gas emissions that have special impacts. These include regulation of nitrous oxide, and regulation of fugitive emissions from digesters and “hot spots” of dairy methane emissions as well as criteria pollutants.
6. Provide technical assistance to dairies in the highly complex ways of managing manure and the ammonia, N20, hydrogen sulfide, and methane it produces.
7. Regulate enteric emissions for all livestock if initial short-term pilot incentive programs do not show a high enough dairy uptake to produce a 20% reduction in enteric emissions by 2030 and 40% by 2040. CARB would set out a schedule for voluntary uptake; and regulate to that schedule if it is not met.

All of these actions are necessary, and we hope sufficient, to meet California’s goals.

For centuries cattle have been sacred in many religions. Nevertheless, when it comes to slowing our planet’s warming, we cannot afford to put livestock in the pantheon of protected emissions sources.

The petition is attached. Thank you for considering it, and these comments.

Sincerely,

Janet Cox, CEO
Climate Action California

Will Brieger, Director
Climate Action California

Daniel Chandler, PhD
Climate Action California

Cc: Katherine Estabrook for transmittal to Members of the California Air Resources Board

BEFORE THE CALIFORNIA AIR RESOURCES BOARD

PETITION FOR RULEMAKING TO REQUIRE REDUCTION OF METHANE FROM DAIRIES AND BEEF CATTLE

PETITION FOR RULEMAKING

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Introduction

California currently does not regulate emissions from livestock facilities— the single largest anthropogenic methane source. There *are* regulations intended to reduce methane emissions from landfills and from oil and gas production and transport facilities. Those existing regulations do not rely on perfect capture technologies, nor are the benefits of those regulations perfectly quantifiable. Rather, they rely on known, reasonably available practices and a few numeric thresholds that require facility operators to act.

Petitioners know of many practices available to reduce livestock methane emissions. No good reason exists for the Board to delay tackling emissions from such facilities. In fact, as set forth below, there are powerful reasons to act as soon as possible to reduce emissions from such facilities.

Rapid reduction of methane will slow global warming and give us time to achieve 1.5°C total warming with CO2 reductions.

In 2018 the IPCC calculated a "carbon budget" of total emissions that would cause warming equal to 1.5°C.[1] In October 2023 this carbon budget was recalculated, and a revised estimate showed that at current emissions rates, the budget will be "expended" in just six years from now, in 2029.[2] Rapid reductions in methane offer an opportunity to slow down increases of 1.5°C or higher. The 2022 Scoping Plan says:

> Human sources of methane emissions are estimated to be responsible for up to 25 percent of current warming. Fortunately, methane's short atmospheric lifetime of ~12 years means that emissions reductions will rapidly reduce concentrations in the atmosphere, slowing the pace of temperature rise in this decade…. The UN's Global Methane Assessment shows that human-caused methane emissions can be reduced by up to 45 percent this decade, which would avoid nearly 0.3°C of global warming by 2045.

Accordingly, the 2021 Global Methane Pledge, announced at COP 26, noted that "[r]apidly 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." (emphasis added)

Neither the scoping plan nor this petition suggests substituting methane reduction for other greenhouse gas reductions. Methane reduction is not the silver bullet that will reverse planetary

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[1] IPCC, 2018: Summary for Policymakers. In: *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty.* Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 3-24. https://doi.org/10.1017/9781009157940.001.

[2] Lamboll, R.D., Nicholls, Z.R.J., Smith, C.J. *et al.* Assessing the size and uncertainty of remaining carbon budgets. *Nat. Clim. Chang.* (2023). https://doi.org/10.1038/s41558-023-01848-5. "We conclude that the RCB for a 50% chance of keeping warming to 1.5 °C is around 250 $GtCO_2$ as of January 2023, equal to around six years of current CO_2 emissions. For a 50% chance of 2 °C the RCB is around 1,200 $GtCO_2$."

heating, but it does represent one of the most effective strategies we have; in light of the significant warming driven by livestock emissions it is surprising that the tools have been left idle.

Methods to control livestock methane emissions exist.

As set out in Appendices B and C, there is a growing understanding of how to minimize methane emissions from manure handling and enteric emissions (from burping and flatulence). For a variety of reasons, California livestock operations have not adopted those practices to any great extent. As noted in CARB's *Final SLCP Strategy*: "The State also has higher per-milking cow methane emissions than most of the rest of the United States, due to the widespread use of flush water lagoon systems for collecting and storing manure."[3] The accepted emissions factors for different manure management practices are shown below.[4] The greatest difference is between pasture-based and lagoon-based practices.

Emission factor of CH_4 from different manure management practices on California dairies.

Manure Management Practices	Emission factor (kg CH_4 per dairy cow per year)
Anaerobic digester	82.24
Anaerobic lagoon	331.98
Daily Spread	2.27
Deep Pit	146.79
Liquid Slurry	146.79
Pasture	6.81
Solid storage	18.16

There are approaches that, if mandated, can minimize methane emissions from manure management. In the face of global warming, and our leadership of the Subnational Methane Action Coalition, that is California's particular obligation.

CARB's Statutory Authority and Obligation to Reduce Livestock Methane

CARB is legally obligated to regulate livestock emissions. SB 1383 (Lara) became law in 2016. It requires a 40% reduction of livestock methane by 2030.[5] As codified, Health & Safety Code section 39730.7, subd. (b)(1) instructs that CARB "shall adopt regulations to reduce methane emissions from livestock manure management ... by up to 40 percent below the dairy sector's and livestock sector's 2013 levels by 2030." Subdivision (b)(2) instructs that CARB "shall" take three specified steps prior to adopting the regulations. By repeatedly using the word "shall," the

[3] https://ww2.arb.ca.gov/sites/default/files/2020-07/final_SLCP_strategy.pdf

[4] Pressman, Eleanor M., Shule Liu, and Frank M. Mitloehner. "Methane emissions from California dairies estimated using novel climate metric Global Warming Potential Star show improved agreement with modeled warming dynamics." *Frontiers in Sustainable Food Systems* 6 (2023): 1072805. Supplementary Data Sheet for Table S2.

[5] https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201520160SB1383

Legislature gave CARB no discretion regarding whether to adopt the regulations in time to achieve the 2030 target.

The Legislature did set conditions regarding when to *implement* the regulations. In section 39730.7, subd. (b)(4) sets out five findings CARB and CDFA must make prior to implementation. Those familiar determinations are typical of virtually all CARB regulations at the promulgation phase. The five determinations boil down to feasibility and cost effectiveness. The five findings are set out in the margin.[6] We note that minimizing leakage is simply a variation on effectiveness, and a trivial concern here because dairies in other states tend to emit significantly less methane per cow.

Because it is mandatory both that the regulations be adopted and that implementation is conditioned on the five findings, it is clear that CARB must design regulations with those five findings in mind. But regulate it must. The Legislature called out just one exception: "[v]oluntary enteric emissions reductions may be used toward satisfying the goals of this chapter."

In addition to SB 1383's mandate, the Legislature has empowered and charged the Board more generally with "monitoring and regulating sources of emissions of greenhouse gases that cause global warming in order to reduce emissions of greenhouse gases."[7]

Preconditions for implementing livestock methane regulations have been met.

As set forth below and throughout this petition, SB 1383's preconditions for implementing regulation have been met.

- The regulations are technologically and economically feasible:

  Below we have pointed to multiple options for reducing methane though manure management. We recognize that for large facilities and big mitigation projects state funding will still be necessary.

- They are cost effective:

[6] Health & Safety Code section 39730 provides, in pertinent part:
(b)(4) [The livestock methane reduction regulations] shall be implemented on or after January 1, 2024, if the state board, in consultation with the department, determines all of the following:
(A) The regulations are technologically feasible.
(B) The regulations are economically feasible considering milk and live cattle prices and the commitment of state, federal, and private funding, among other things, and that markets exist for the products generated by dairy manure management and livestock manure management methane emissions reduction projects, including composting, biomethane, and other products. The analysis shall include consideration of both of the following:
(i) Electrical interconnection of onsite electrical generation facilities using biomethane.
(ii) Access to common carrier pipelines available for the injection of digester biomethane.
(C) The regulations are cost effective.
(D) The regulations include provisions to minimize and mitigate potential leakage to other states or countries, as appropriate.
(E) The regulations include an evaluation of the achievements made by incentive-based programs.

[7] Health & Saf. Code §38510. *See generally* Health & Saf. Code Div. 25.5, Div. 26, and §39600.

The EPA just set the social cost of carbon at $190 per metric ton of carbon emitted.[8] In the Progress Report reductions in methane through AMMP ($61 per metric ton CO_2e) or digesters ($9 per metric ton) are shown to be among the most cost-effective ways of cutting warming emissions.[9] Regulation plus incentives plus technical assistance would be even more effective and far less costly than not regulating the emissions.

- They include measures to minimize leakage, that is, dairies moving their cows and emissions out of state:

  Please see the discussion below at page 16 as well as the thorough discussion in the UCLA Emmett Center Policy Report cited in the footnote.[10] Dairies are unlikely to move, and unlikely to emit at the same level elsewhere.

- They include an evaluation of the progress made by incentives alone:

  The 2022 Progress Report, the 2021 Emissions Inventory, and the 2022 Scoping plan meet this requirement.

- Enteric emissions reductions shall be achieved only through incentive-based mechanisms until certain conditions are met.

  This proposal recognizes that enteric emissions could be reduced initially with a voluntary program. At the point at which CARB decides to regulate enteric emissions it would have the obligation to establish that the SB 1383 conditions for regulation of enteric methane had been met.

California is not on track to achieve the SB 1383 and Scoping Plan targets.

The December 2023 Emissions Inventory states: "Livestock emissions peaked in 2012 at 23.9 $MMTCO_2e$ and have decreased by 2.2 $MMTCO_2e$ (9.4%) to 21.7 $MMTCO_2e$ as of 2021."[11] If

[8] https://www.epa.gov/environmental-economics/scghg

[9] The California Climate Investments program that spends cap-and-trade funds has costs per metric ton of CO_2e emitted that range from $27 for Fluorinated Gases Emission Reduction Incentives to $2,129 for Community Air Protection Incentives. https://ww2.arb.ca.gov/sites/default/files/auction-proceeds/cci_annual_report_2023.pdf#page=37 All these costs are the costs to the state. Digesters and AMMP usually have private funding as well.

[10] Ruthie Lazenby, Mitigating Emissions From California's Dairies: Considering the Role of Anaerobic Digesters in Mitigating Emissions from California's Dairies . UCLA, Emmet Institute on Climate Change and the Environment. January 2024:

[11] California Greenhouse Gas Emissions from 2000 to 2021: Trends of Emissions and Other Indicators. December 14, 2023. https://ww2.arb.ca.gov/sites/default/files/2023-12/2000_2021_ghg_inventory_trends.pdf?utm_medium=email&utm_source=govdelivery. However, the methodology used in the report is very conservative, not including all digesters and excluding AMMP projects. A CARB spokesperson said that in assessing the 40% reduction required by SB 1383 they may "need to look at other data beyond that reflected in the inventory. As such, we will make decisions about future analyses based on the best available data at that time." [Personal Communication with Stephen Weller January 8, 2024: stephen.weller@arb.ca.gov] This seems to indicate CARB has no currently approved method of measuring progress toward the 2020 goal.

emissions continue to drop at 9.4% per decade, by 2030 there will be a drop of less than 20% -- nowhere close to the mandated 40% reduction.

The CARB 2022 Progress Report makes clear that as of that date we were not on track to achieve the emissions reductions SB 1383 calls for. There are no indications that this situation will change absent regulations.[12]

The 2022 Scoping Plan estimates that about 15 MMTC02e (of 22 $MMTCO_2e$) agricultural methane emissions can be reduced using known methods. To date, almost halfway to 2030 since SB 1383's enactment, CARB estimates reductions of only about 2 $MMTCO_2e$ since 2013 resulting from incentives in the LCFS and grants through several other programs that fund improved manure handling.[13] The required 40% reductions (9 $MMTCO_2e$) appear out of reach using only incentives. To reach the 40%, the Progress Report says the *rate* of emissions reductions seen in 2018 – 2022 will need to double.

The Scoping Plan states that "In consideration of pace of deployment of [livestock] methane mitigation strategies and the scale of complimentary incentives, consider regulation development to ensure that the 2030 target is achieved, assuming the conditions outlined in SB 1383 are met."[14]

Are incentives working? Recent funding does not come close to the amounts the Progress Report recommended, nor does it reflect the importance of methane reduction.

- The Progress Report recommended expenditures of $75 million a year. In the two budget years since that report, various allocations together with US Department of Agriculture grants have been only about $49 million per year.
- The number of projects actually being funded will not get us to the 210 digesters and 210 AMMP projects needed by 2030 under one Progress Report scenario.

The livestock methane problem may be worse than we understand; regulatory attention is likely to improve our ability to measure this important pollutant.

Discrepancies between models used by CARB and on-the-ground measurement of methane mean CARB may mean CARB is underestimating the amount of methane that needs to be reduced. CARB estimates of methane emissions are modeled rather than measured. CARB's model for methane emissions in agriculture is based on that of the federal EPA's, which in turn is based on that of the IPCC. The peer reviewed literature contains numerous studies showing that measured emissions are usually higher than modeled emissions.

A rulemaking process might sort out which models and measurements should be used. In any event, the precautionary principle suggests that our climate regulations ignore agricultural

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[12] A*nalysis of Progress toward Achieving the 2030 Dairy and Livestock Sector Methane Emissions Target (March 2022).* This report will be cited hereafter as "Progress Report." The total amount needed to achieve a 40% reduction from 2013 levels is 9 $MMTCO_2e$ per year (including enteric emissions).
[13] Ibid.
[14] 2022 scoping plan documents, Final 2022 Scoping Plan Update and Appendices https://ww2.arb.ca.gov/our-work/programs/ab-32-climate-change-scoping-plan/2022-scoping-plan-documents (2022). Page 232.

methane at our collective peril. Some of the studies raising questions about modeled emission levels include the following.

- "Modeled methane emissions underestimated field measurement means for most manure management practices…. Our results suggest that current greenhouse gas emission factors generally underestimate emissions from dairy manure and highlight liquid manure systems as promising target areas for greenhouse gas mitigation.[15]
- "When methane is measured outside of the lab, in the air directly above manure tanks, pits, and piles, emissions tend to be greater than models predict, sometimes by more than 300%.... N_2O emissions appear to be similarly or more dramatically higher than bottom-up estimates when assessed using top-down methods.[16]
- "Comparisons between measured and modeled CH_4 emissions showed that both the IPCC methane conversion factor (0.17) for cool climates (10 °C or less), and the USEPA model, underestimated annual emissions by up to 60%."[17]
- "Measured CH_4 emissions [from 14 dairies] were 60% higher than the rates reported in the California Air Resources Board (CARB) inventory."[18]

These studies make the point that CARB's model-based estimates of methane emissions and reductions from digesters and AMMP are likely *under* estimates. And they suggest that neither the numerator (2030 levels) or denominator (2013 levels) of the 40% reduction goal is accurate. The high stakes make any misjudgment dangerous.

The goal for livestock methane should be to stabilize methane emissions at as low a level as possible.

Because methane is a short-lived source of warming, reducing emissions leads to reduced atmospheric concentrations in a short time, relative to what can be accomplished by reducing CO_2 emissions. As atmospheric concentrations decline, climate forcing declines linearly. Given the predicament in which we find ourselves, we need to maximize that effect. To realize the advantages of reducing methane quickly we need goals that are much more ambitious than "climate neutral" for sectors emitting methane.

We note that SB 32 requires a 40% reduction in greenhouse gas emissions by 2030 but uses a 1990 baseline; in 1990 cumulative methane emissions from livestock were about 200 MMT.[19] SB 1383 uses a 2013 baseline when those emissions were 750 MMT, near the industry's historic peak. In other words, the required 40% reduction is not ambitious. When CARB acts, the goal should be as ambitious as reasonably possible. The post-1990 emissions increases should not be accepted as a baseline. Accordingly, the Board should skeptically examine the

[15] Owen, Justine J., and Whendee L. Silver. "Greenhouse gas emissions from dairy manure management: a review of field-based studies." *Global change* biology 21, no. 2 (2015): 550-565.
[16] Hayek, Matthew N., and Scot M. Miller. "Underestimates of methane from intensively raised animals could undermine goals of sustainable development." *Environmental Research Letters* 16, no. 6 (2021): 063006. For documentation see the references cited in the article.
[17] Baldé, Hambaliou, Andrew C. VanderZaag, Stephen Burtt, Leigh Evans, Claudia Wagner-Riddle, Raymond L. Desjardins, and J. Douglas MacDonald. "Measured versus modeled methane emissions from separated liquid dairy manure show large model underestimates." *Agriculture, ecosystems & environment* 230 (2016): 261-270.
[18] Vechi, N. T., et al. (2023). Ammonia and methane emissions from dairy concentrated animal feeding operations in California, using mobile optical remote sensing. Atmospheric Environment, 293(15).
[19] Derived using GWP*, which is appropriate for short-lived climate pollutants.

"climate neutral" goals some dairy industry advocates support; we should do more than limit *additional* warming after the industry ramped up its growth and emissions to the planet's detriment.[20]

In recognition of CARB's demonstrated ability to use its rulemaking process to craft effective, feasible regulations, this petition does not propose specific regulatory language. The ultimate standard, however, should require the best available technology and practices.

California's failure to regulate combined with LCFS incentives for livestock methane production act to preserve California's unusually high-emission livestock practices.

If California were to regulate livestock methane, it is likely that our dairies and feedlots would evolve to adopt the lower emission manure handling practices employed in other states and nations. (See Appendix B.) The high-emission practice of collecting liquid manure in lagoons is unusually prevalent in California. Other manure handling methods yield much less methane.

Absent regulations, any methane capture is viewed as voluntary; there is no policy pressure to reduce methane creation at livestock facilities. Instead, California's Low Carbon Fuel Standard (LCFS) seems to incentivize the production of *additional methane*, so long as some[21] of that additional methane is captured and used for an internal combustion vehicle engine. CARB's LCFS program rewards dairies and feedlots that create and capture extra methane from liquid manure lagoons. If the farmer builds a lagoon, then builds a digester to collect the resulting methane, the gas can be cleaned and used for transportation, generating extensive credits. Those valuable credits are premised in part on the assumption that the methane would otherwise have escaped as "fugitive" emissions. That treatment ignores the fact that by choosing to handle manure without a lagoon, less methane could have been produced in the first place.

It is difficult to overstate the impact of the choice to use the flush/lagoon approach to manure management. Worldwide, methane emissions from managing dairy and beef manure are roughly 15% of the total; enteric emissions make up the other 85%.[22] In the U.S. 24% of livestock methane is from manure management.[23] But in California, manure handling generates 45% of livestock methane emissions, and for dairies it is 56%[24] As UC Davis researchers said in 2023, "Methane emissions originating from manure are produced primarily from anaerobic

[20] See, e.g., McCabe, C. J., H. M. Mashad, and F. M. Mitloehner. "The path to climate neutrality for California dairies." *CABI Reviews* 2023 (2023).
[21] The LCFS does not account for many of the GHG emissions associated with the dairies large enough to support an expensive anaerobic digester, including sizable enteric emissions from the herd, manure emissions upstream of the digester, emissions from the resulting digestate, and any leaking methane above the CA-GREET model's modest assumptions.
[22] https://asm.org/articles/2023/june/ruminant-methanogens-as-a-climate-change-target
[23] https://www.epa.gov/ghgemissions/overview-greenhouse-gases
[24] https://ww2.arb.ca.gov/ghg-slcp-inventory

settling basins and lagoons, which are the most common manure storage systems in the state."[25] This method is used far less in other parts of the U.S.[26]

A rule limiting methane emissions from livestock facilities would make methane a controllable pollutant, rather than an extra credit opportunity that soaks up policy attention (and diverts LCFS credit revenue that could have gone to zero emission fuel providers, such as owners of EV charging stations).

Avoided methane crediting for dairies is unique under the LCFS. No other industry is treated as if their methane pollution is naturally part of the baseline and then lavished with large financial incentives for simply capturing some of their own pollution. Instead, oil companies are regulated and penalized for their emissions. Likewise, landfill operators are not awarded large, avoided emission credit for capturing methane escaping from landfills; they are required to do so.

Regulation might identify and control "hot spot" agricultural methane emissions.

Between 2016 and 2018 California carried on an aerial surveillance of methane point sources, including 443 Concentrated Animal Feeding Operation. Point source plumes of methane from dairy manure were detected at 215 farms and the measured methane comprised 26% of that found in all types of point sources.[27] Those efforts reveal that we have problem spots, but that local and more consistent monitoring – which could be included in a regulation – will be necessary to accurately assess emissions.

Regulation of livestock facilities would also control air pollution in the heavily polluted Central Valley.

"Criteria pollutants" – particulate matter, carbon monoxide, nitrogen oxide, sulfur dioxide, lead, and reactive organic gases – are linked to multiple adverse health effects including, among others, premature death, hospitalizations and emergency department visits for exacerbated chronic disease, and increased symptoms such as coughing and wheezing."[28]

Livestock emissions have been identified as an important source, as noted in this 2021 study in the Proceedings of the National Academy of Science:

> Poor air quality is the largest environmental health risk in the United States and worldwide, and agriculture is a major source of air pollution. Nevertheless, air quality has been largely absent from discussions about the health and environmental impacts of food. We estimate the air quality–related health

[25] El Mashad, Hamed M., Tyler J. Barzee, Roberta Brancher Franco, Ruihong Zhang, Stephen Kaffka, and Frank Mitloehner. "Anaerobic Digestion and Alternative Manure Management Technologies for Methane Emissions Mitigation on Californian Dairies." *Atmosphere*14, no. 1 (2023): 120.
[26] 55% of US dairies use lagoons. Annex 3.11. Methodology for Estimating CH_4 and N_2O Emissions from Manure Management. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2014 USEPA, Washington, DC, USA (2016)
[27] Riley Duren, Andrew Thorpe, Ian McCubbin. The California Methane Survey. California Energy Commission. Contract 500-15-004. July 2020. https://www.energy.ca.gov/sites/default/files/2021-05/CEC-500-2020-047.pdf
[28] https://ww2.arb.ca.gov/criteria-pollutant-emission-inventory-data

> impacts of agriculture in the United States, finding that 80% of the 15,900 annual deaths that result from food-related fine particulate matter ($PM_{2.5}$) pollution are attributable to animal-based foods…. Pollutants include primary $PM_{2.5}$ and secondary $PM_{2.5}$ formed from precursor gases (NH_3, NOx, NMVOCs, and SO_2).[29]

Beef cattle and pork are at the top of the list, but dairies contribute 1,800 pollution-related premature deaths annually in the US, and California has the most milk cows of any state (18% of all milk cows in the US).[30] Improved manure management could reduce many of the deaths and health effects attributable to $PM_{2.5}$ and other criteria pollutants.

Large dairies have many negative effects on human health as well as on air and water. It is hard to separate methane from other emissions and health effects as they cluster with CAFOs and manure applied to fields. One study reviewing the literature identified four major health effects: respiratory effects, MRSA, Q fever and stress and mood consequences. Several others were also identified as risks.[31] In general, the main pollutants that affect health are ammonia, methane, particulate matter and hydrogen sulfide. In the study on premature deaths due to agricultural emissions cited above, 97% were attributable to $PM_{2.5}$ or ammonia. But as California lab experiments have shown, biomethane contains hundreds of volatile organic compounds, several of concern.[32] And the methane released by the lagoons has multiple hazards: "The ozone triggered by methane releases, for example, contributes to asthma and other serious respiratory problems. Tulare is the fifth most ozone-polluted county in the United States, according to the American Lung Association."[33] Dairies produce 21% of the ozone in the San Joaquin valley.[34]

Ammonia

Excess nitrogen, in the form of ammonia, is the source of much of the air and water pollution in the San Joaquin Valley. Manure management must form the backbone of attempts to address the problems. Ammonia as a gas directly contributes to generation of $PM_{2.5}$.[35] It also pollutes ground water and surface water.[36] It contributes to N_2O emissions. Concentrations of ammonia

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[29] Domingo, Nina GG, Srinidhi Balasubramanian, Sumil K. Thakrar, Michael A. Clark, Peter J. Adams, Julian D. Marshall, Nicholas Z. Muller et al. "Air quality–related health damages of food." *Proceedings of the National Academy of Sciences* 118, no. 20 (2021): e2013637118.

[30] https://www.statista.com/statistics/194962/top-10-us-states-by-number-of-milk-cows/ https://www.nass.usda.gov/Newsroom/2023/01-31-2023.php#:~:text=The%20number%20of%20milk%20cows,%2C%20down%204%25%20from%202022.

[31] Casey, Joan A., Brent F. Kim, Jesper Larsen, Lance B. Price, and Keeve E. Nachman. "Industrial food animal production and community health." *Current environmental health reports* 2, no. 3 (2015): 259-271.

[32] https://content.govdelivery.com/accounts/CARB/bulletins/33053ee

[33] https://insideclimatenews.org/news/09082021/california-dairy-methane-emissions/

[34] https://www.cdfa.ca.gov/agvision/docs/Air_Quality_and_Agriculture.pdf

[35] Hristov, Alexander Nikolov. "Contribution of ammonia emitted from livestock to atmospheric fine particulate matter (PM2. 5) in the United States." *Journal of Dairy Science* 94, no. 6 (2011): 3130-3136.

[36] Rex, Elias, "Geospatial Applications to Mitigate Concentrated Animal Feeding Operations From Impacting Surface Water Resources" (2020). Electronic Theses, Projects, and Dissertations.1108 https://scholarworks.lib.csusb.edu/etd/1108/?utm_source=scholarworks.lib.csusb.edu%2Fetd%2F1108&utm_medium=PDF&utm_campaign=PDFCoverPages. In this study percentage of land used by CAFOs correlated with pollution.

from dairies were found by a NOAA aerial study to be 3-20 times those predicted by CARB models.[37] Beef cattle feedlots are also a large source of ammonia.[38]

A particular concern is that the digestate left after digesting manure may contain far higher percentages of ammonia than non-digested manure. Ammonia can be dangerous to persons, and it can contaminate water and soil and lead to PM 2.5 pollution.[39] Digestate itself produces methane and is in fact the largest source of fugitive methane in the supply chain for biomethane, up to 15% of the methane produced.[40] Another study found 12% of methane was produced by the digestate.[41] In a study of a digester in Italy, 27% of the methane produced was emitted by the digestate rather than being captured.[42]

N_2O

N_2O is a potent global warming agent with a GWP_{100} of 273. Application of fertilizer is the main N_2O source. If fertilizer is applied on crops in small doses in the spring and early summer, N_2O emissions are reduced compared to storing fertilizer all winter. Agricultural nitrous oxide is clearly a greenhouse gas that should be reduced and controlled. The European Nitrates Directive shows that legal regulation of these pollutants is possible and results in improved environmental and climate outcomes.

Hydrogen Sulfide

Hydrogen Sulfide poses health hazards.[43] San Joaquin Valley residents consistently complain about the smells of dairies. The smells are caused by hydrogen sulfide. Chronic exposure to low levels of hydrogen sulfide have been found to be associated with respiratory symptoms and ocular and neurological disorders.[44] Higher levels are more dangerous. In some cases humans

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[37] Nowak, J. B., J. A. Neuman, R. Bahreini, A. M. Middlebrook, J. S. Holloway, S. A. McKeen, D. D. Parrish, T. B. Ryerson, and M. Trainer. "Ammonia sources in the California South Coast Air Basin and their impact on ammonium nitrate formation." *Geophysical Research Letters* 39, no. 7 (2012).

[38] Sun, Jianlei, Mei Bai, Jianlin Shen, David WT Griffith, Owen T. Denmead, Julian Hill, Shu Kee Lam, Arvin R. Mosier, and Deli Chen. "Effects of lignite application on ammonia and nitrous oxide emissions from cattle pens." *Science of the Total Environment* 565 (2016): 148-154.

[39] https://insideclimatenews.org/news/19092022/dairy-digesters-methane-california-manure/? The state has recently signed a contract to find out more about ammonia and nitrous oxide from digestate. Michael A. Holly, Rebecca A. Larson, J. Mark Powell, Matthew D. Ruark, Horacio Aguirre-Villegas, Greenhouse gas and ammonia emissions from digested and separated dairy manure during storage and after land application, Agriculture, Ecosystems & Environment, Volume 239, 2017, Pages 410-419, ISSN 0167-8809, https://doi.org/10.1016/j.agee.2017.02.007. (https://www.sciencedirect.com/science/article/pii/S0167880917300701)

[40] Bakkaloglu, S., et al. (2022). Methane emissions along biomethane and biogas supply chains are underestimated. One Earth, 5(6).

[41] Balde, Hambaliou, Andrew C. VanderZaag, Stephen D. Burtt, Claudia Wagner-Riddle, Anna Crolla, Raymond L. Desjardins, and Douglas J. MacDonald. "Methane emissions from digestate at an agricultural biogas plant." *Bioresource technology* 216 (2016): 914-922

[42] Döhler, Helmut, Anke Niebaum, Ursula Roth, Thomas Amon, Paolo Balsari, and George Friedl. "Greenhouse Gas Emissions and Mitigati-On Costs in Two European Biogas Plants." *Proceedings of the Gülzower Fachgespräche, Berlin, Germany* (2009): 3-4.

[43] OSHA lists health hazards based on level of exposure. https://www.osha.gov/hydrogen-sulfide/hazards

[44] Lewis, R. Jeffrey, and G. Bruce Copley. "Chronic low-level hydrogen sulfide exposure and potential effects on human health: a review of the epidemiological evidence." *Critical Reviews in Toxicology* 45, no. 2 (2015): 93-123.

have died from exposure; including approximately 75 manure-related fatalities in the US.[45] A study of 43 British Columbia dairies measured concentrations of hydrogen sulfide directly where operators were stirring manure and at other places of potential high levels. Under B.C. regulations, hydrogen sulfide is a health risk at greater than 10 ppm, with 5 ppm requiring "action.".[46] The study found: "Action levels were exceeded in 30% of operator measures and 64% of potential exposure measures while 20% of operator and 53% of potential peak hydrogen sulfide measures exceeded 10 ppm."[47] Building design,[48] manure mixing speed and duration as well as, temperature, pH, and nutrition level of the feed affect hydrogen sulfide concentration.[49] Use of gypsum bedding is also a source of dangerously high hydrogen sulfide in manure being agitated.[50] Use of iron oxide as a manure additive can mitigate hydrogen sulfide releases.[51] Digesters reduce hydrogen sulfide emissions.

NOx from digesters.

Anaerobic digesters at livestock facilities offer another source that could be beneficially regulated when CARB regulates such facilities. CARB's 2017 SLCP Strategy noted:

> [S]trategies that reduce or eliminate criteria pollutant and toxic emissions should be encouraged in both incentive and regulatory programs, particularly in areas with severe or extreme air pollution. Using ARB-certified distributed generation technologies, such as microturbines or fuel cells, can significantly cut NO_x emissions compared to internal combustion-based power generation. Injecting upgraded biomethane into the natural gas pipeline can avoid most new combustion or associated emissions.

Fuel cells using biogas produce virtually no air pollution. Currently digesters funded through CDFA must meet a 0.50 lb/MWhr requirement for NOx. Digesters funded through other means, such as LCFS, have no such requirement. Hence to control the air pollution created by

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[45] Andriamanohiarisoamanana, Fetra J., Yushi Sakamoto, Takaki Yamashiro, Seiichi Yasui, Masahiro Iwasaki, Ikko Ihara, Osamu Tsuji, and Kazutaka Umetsu. "Effects of handling parameters on hydrogen sulfide emission from stored dairy manure." *Journal of environmental management* 154 (2015): 110-116. Wyatt Bechtel. Hydrogen Sulfide Health Hazards. *Dairy Herd Management.* https://www.dairyherd.com/news/business/hydrogen-sulfide-health-hazards

[46] OSHA lists these levels: "NIOSH Recommended Exposure Limit (REL): 10 ppm, 10-minute ceiling. Concentration considered immediately dangerous to life and health (IDLH): 100 ppm. ACGIH® recommends a threshold limit value (TLV®) of 1 ppm as an 8-hour time weighted average (TWA) and a short-term exposure limit (STEL) of 5 ppm." https://www.osha.gov/hydrogen-sulfide/standards

[47] O'Leary, T., K. Merkowsky, C. Trask, W. Bennett, and S. Kirychuk. "Operator and Potential Exposure to Hydrogen Sulfide: A Study of the British Columbia Dairy Industry." *Journal of Agromedicine* 26, no. 4 (2021): 381-388.

[48] Shi, Zhifang, Xiaoqin Sun, Yao Lu, Lei Xi, and Xin Zhao. "Emissions of ammonia and hydrogen sulfide from typical dairy barns in central China and major factors influencing the emissions." *Scientific Reports* 9, no. 1 (2019): 13821.

[49] Andriamanohiarisoamanana, Fetra J., Yushi Sakamoto, Takaki Yamashiro, Seiichi Yasui, Masahiro Iwasaki, Ikko Ihara, Osamu Tsuji, and Kazutaka Umetsu. "Effects of handling parameters on hydrogen sulfide emission from stored dairy manure." *Journal of environmental management* 154 (2015): 110-116.

[50] Fabian-Wheeler, Eileen E., Michael L. Hile, Dennis Murphy, Davis E. Hill, Robert J. Meinen, Robin C. Brandt, Hershel A. Elliott, and Daniel Hofstetter. "Operator exposure to hydrogen sulfide from dairy manure storages containing gypsum bedding." *Journal of agricultural safety and health* 23, no. 1 (2017): 9-22.

[51] Eileen E. Fabian, Additive to Mitigate Odor and Hydrogen Sulfide Gas Risk from Gypsum Bedded Dairy Manure. https://lpelc.org/additive-to-mitigate-odor-and-hydrogen-sulfide-gas-risk-from-gypsum-bedded-dairy-manure/

digesters we need a regulation which requires fuel cells or, at minimum, turbines (about 5 times less pollution than ICE). The Progress Report does state that the San Joachin Valley is highly polluted and ICE engines are the "least desirable option." It also points out that fuel cells produce a small fraction of the NOx and particulate matter that internal combustion engines do.

Absent regulatory requirements, the CARB Progress Report assumes: "that project developers will select the digester technology option that is most suitable for their facility." At the time of the report in 2022, only 3 digesters had, or were planning, fuel cells. A Fresno-based project that develops electricity for EV charging without combustion by using fuel cells and biogas claimed in January 2024 to be the first of its kind.[52] The Progress Report also discusses microturbines, which produce several times less NOx than internal combustion engines. But again there is no requirement to use them, and funding does not seem to indicate they are anticipated, as they are also more expensive than ICE.

Table 1 shows the NOx permissible according to CDFA grant standards, plus emissions for fuel cells, microturbines and the new Low NOx standard for mobile sources. Clearly CDFA is not setting a standard that will hold NOx to anything close to the possible level.

Table 1: Typical NOx Emissions Compared to CDFA Standard

CDFA standard in digester grant program	0.50 lb/MWhr
Fuel cell NOx	0.00037 lb/MWhr
Capstone Microturbine NOx	0.03122 lb/MWhr
California Low NOx Standard	0.03280 lb/MWhr

Regulatory standards could result in the use of better technologies and performance monitoring at facilities with digesters.

Along with regulation, CARB and CDFA should provide technical assistance.

There is a great deal of technical assistance available to dairies from non-profits, universities, and government agencies. The Regional Dairy Farmer-to-Farmer AMMP Project Tours and Awareness Outreach is specifically for AMMP projects. However, implementing methane and pollution regulations will require more. Dairies are highly complex chemical factories, and affecting one emission can have many knock-on effects for other emissions or other facets of dairy production. For example, there can be a tradeoff between methane and nitrous oxide in choosing between flush and dry/scrape manure management. Digesters solve some problems but at the cost of increased ammonia, and probably nitrous oxide, in the digestate.

Applying for funding for digesters or AMMP is complicated and will continue to be so when the financing mechanisms change. Applicants may need assistance with such tasks as permitting, finding contractors and budgeting.

Regulating methane and other polluting gases on all dairies will mean hundreds of dairy operators will need to think anew about their practices. "Dairy farmers must understand the benefits and challenges changes to manure management will have on resource allocation (labor, equipment, land), operational changes, economic opportunities or costs and whole-farm

[52] https://www.caclimateinvestments.ca.gov/2022-profiles-1/ddrdpbar20

environmental impacts and benefits."[53] The regulations are likely to be far more effective if technical support is available to help with both the how and the why of new standards and funding arrangements.

[53] California Department of Food and Agriculture Alternative Manure Management Program Demonstration Project - Final Report. March 2022. https://www.cdfa.ca.gov/oefi/ammp/docs/AMMP_DemoAPFF2019_FinalReport.pdf

Leakage will be minimal, especially if financial support and technical assistance are provided.

Opponents of regulation typically claim that regulation will create unsustainable costs that cannot be passed on to consumers. The approach we have suggested requires each dairy to take some action, but for high-cost items like digesters, vermifiltration, or solid/liquid separation the state's approach should continue to provide financial support. In addition, many of the larger dairies have already installed digesters or AMMP mitigation measures, and e less affected. Comments at ARB Board meetings and the high number of AMMP applications have made it clear that the overwhelming majority of dairy owners want to contribute to methane mitigation if they can do so affordably and view air and water pollution control as part of sustainable dairying.

As we noted above, other states have lower percentages of methane from manure management. So concerns that we will be exporting methane pollution elsewhere are overblown. Moreover, modern dairies represent significant capital investments that are unlikely to be abandoned.

The concept of leakage also assumes that other states will not regulate. However, we hope California's example will encourage several other progressive dairy states and the EPA to realize that there is no need to let agriculture be the only sector not contributing to solving the climate crisis. With the new subnational government methane reduction program that California is spearheading, our example will have an even broader impact.

CONCLUSION

Controlling emissions – especially methane – from livestock facilities is a necessary, appropriate and feasible step. Methane reductions are the single most effective tool we have to prevent dangerous climate warming in the next decade or two. Because California's incentive-based efforts have fallen far short, it is time to directly regulate the largest anthropogenic methane source, just as we do with other major sources of climate pollution. Aside from coming up short on results, incentives are subject to budgetary vicissitudes. We cannot take the gamble that voluntary programs might or might not have sufficient funding to spare us from catastrophe.

As described in this petition, there are available methods to accomplish reductions. There are also myriad health and environmental benefits that could be realized from measures that reduce not just methane but various criteria pollutants associated with concentrated animal feeding operations.

The Legislature has already given the Board a mandate to regulate. We urge CARB to once again stand tall and stride briskly.

APPENDIX A: Measuring Emissions

UC Riverside and Lawrence Berkeley researchers have developed two methods to measure methane on individual farms by bringing together existing data (and artificial intelligence). CARB should adopt one or both.

Dairy farmers already must report a variety of measures to different administrative agencies. These can be converted into a system that allows CARB and other agencies concerned with dairy pollution to profile emissions from all 1,400 dairy farmers not just the 172 who have AMMP grants and the 225-250 who have digester funding. UC Riverside researchers did this for 2019 data. It can be adopted by CARB.

> The locations of 1,326 dairy farms in California were determined by inspection of Google Earth satellite imagery. Enteric emissions at each dairy were derived from the number of cattle, dry matter intake, neutral detergent fiber in the diet, and milkfat at the dairy. Estimates of herd numbers and demographic categories came from three sources, the Regional Water Quality Control Board, San Joaquin Valley Air Pollution Control Board, and the US Department of Agriculture National Agricultural Statistics Survey. Manure management emissions were estimated by applying equations of the California Air Resources Board to the facility level with data from the San Joaquin Valley Air Pollution Control District permits, local animal management data, and regional differences in manure management…. This dataset can serve as a planning tool for mitigation, as a prior for estimating atmospheric observation-based emissions, attribution of emissions to a specific facility, and to validate CH4 emissions reductions from management changes.[54]

A 2021 study of an area encompassing 600 dairies in the San Joaquin Valley concluded the new measurements were very close to the farm scale method.[55] And a 2023 aerial survey of the San Joaquin Valley also validated this method.[56]

Some of the same researchers plus researchers from Lawrence Berkeley National Laboratory developed a method of mapping San Joaquin Valley dairies and measuring herd size and methane emissions that uses hundreds of thousands of tiled aerial photographs taken annually by the US government and processed by artificial intelligence. Their method correlates .96 with

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[54] MARKLEIN, AR, D. MEYER, ML FISCHER, S. JEONG, T. RAFIQ, M. CARR, and FM HOPKINS. "Methane Emissions from Dairy Sources (Vista-CA), State of California, USA, 2019." *ORNL DAAC* (2021); and, Marklein, Alison R., Deanne Meyer, Marc L. Fischer, Seongeun Jeong, Talha Rafiq, Michelle Carr, and Francesca M. Hopkins. "Facility-scale inventory of dairy methane emissions in California: implications for mitigation." *Earth System Science Data* 13, no. 3 (2021): 1151-1166.

[55] Heerah, Sajjan, Isis Frausto-Vicencio, Seongeun Jeong, Alison R. Marklein, Yifan Ding, Aaron G. Meyer, Harrison A. Parker et al. "Dairy methane emissions in California's San Joaquin Valley inferred with ground-based remote sensing observations in the summer and winter." Journal of Geophysical Research: Atmospheres 126, no. 24 (2021): e2021JD034785. https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1029/2021JD034785

[56] Schulze, B.C., Ward, R.X., Pfannerstill, E.Y., Zhu, Q., Arata, C., Place, B., Nussbaumer, C., Wooldridge, P., Woods, R., Bucholtz, A. and Cohen, R.C., 2023. Methane emissions from dairy operations in California's San Joaquin Valley evaluated using airborne flux measurements. *Environmental Science & Technology*.

the ground-truthed method above and highly with other corroborating data.[57] The method was also applied to calculating the reductions attributable to anaerobic digesters. This means there are two available reliable methods CARB can adopt which can be used independently or synergistically. The UC Riverside researcher have also developed an accurate on-the-ground method for measuring lagoon emissions, although it requires access to the property.[58]

In 2022 the Legislature passed AB 1775,[59] which required CARB to develop by January 1, 2025, standard methods for tracking greenhouse gas emissions and reductions, including carbon dioxide, methane and nitrous oxide. The two methods we have detailed would take CARB a very long way. We believe they could be modified to track nitrous oxide and ammonia as well.

APPENDIX B: Abatement Methods -- Manure

Numerous methods, other than anaerobic digesters, exist to reduce methane emissions from manure lagoons.

Digesters are in themselves a neutral technology. There are hundreds of thousands of very small digesters on farms in India and thousands of digesters in Europe used at waste treatment facilities. Digesters in the United States can be cost-effective with as few as 300 cows.[60] Digesters have some inherent benefits besides avoiding the release of methane, including reducing odors, the spread of pathogens, and leakage of nitrogen from the system.

Aside from anaerobic digesters, though, there are effective ways to reduce lagoon methane (and other undesired greenhouse or polluting gases)

1. Methane can be captured and flared as it is from natural gas wells. A 2016 study of New York state dairy emissions projected methane release reductions to 2022 using covers and flaring. For a projected 662 storage units the total cost would be $224 million, and it would mitigate 62% of manure methane. The cost per liter of milk would be $0.005."[61]

   While feasible, covering and flaring is not ideal. For a large dairy, flaring is not a cheap option. For 4,000 cows the capital costs are around $3 million. However, a 2022 study found that flaring actually only destroys 91% of methane rather than 98% as had been

[57] Jeong, Seongeun, Marc L. Fischer, Hanna Breunig, Alison R. Marklein, Francesca M. Hopkins, and Sebastien C. Biraud. "Artificial intelligence approach for estimating dairy methane emissions." *Environmental science & technology* 56, no. 8 (2022): 4849-4858.
[58] Thiruvenkatachari, Ranga Rajan, Valerie Carranza, Faraz Ahangar, Alison Marklein, Francesca Hopkins, and Akula Venkatram. "Uncertainty in using dispersion models to estimate methane emissions from manure lagoons in dairies." *Agricultural and Forest Meteorology*290 (2020): 108011.
[59] AB 1757 (Garcia 2022), Cal. Health & Saf. Code, §38561.5, subd. (d).
[60] Greenhouse Gas Mitigation Options and Costs for Agricultural Land and Animal Production within the United States. USDA. 2013.
https://www.usda.gov/sites/default/files/documents/GHG_Mitigation_Options.pdf
[61] Wightman, Jenifer L., and Peter B. Woodbury. "New York dairy manure management greenhouse gas emissions and mitigation costs (1992–2022)." *Journal of environmental quality* 45, no. 1 (2016): 266-275.

previously believed.[62] In addition, flaring releases many toxic co-products.[63] Among these are black carbon, another SLCP, and CO2, CO, CH4, NOx, N2O, H2S, hydrocarbons, and PM. Hydrogen sulfide can be very toxic to humans and nitrous oxide is another high potency gas that causes greater warming than CO2.[64]

2. Methane can be aerated so that the lagoon does not produce the anaerobic conditions that produce methane.[65]
3. Solids/liquid separation can be increased to reduce methane production. This method is the mainstay of California's Alternative Manure Management Program.[66]
4. Flush systems can be wholly or partially converted to dry, scrape systems. "Converting Californian dairies from flushing to scraping manure management strategies has the potential to reduce methane and other gases' emissions by diverting manure away from storage lagoons."[67] Rather than flushing, manure is collected using mechanical scrapers or vacuum trucks.[68] The separated manure can be dried in a variety of ways, including solar, gas heating and composting.[69] Composting with biochar emits far less methane: "We found that biochar-composting reduces CH4 by 79%, compared to composting without biochar…. If biochar-composting replaces manure stockpiling and complements anaerobic digestion, California could meet SB 1383 with 132 less digesters."[70]

   A recent paper by UCD researchers projected that the 40% reduction of SB 1383 could be achieved simply by converting flush to dry: "We assumed the 40 percent reduction goal would be met by 2030 and assumed a constant rate of reduction to meet these goals from 2018 to 2030. Such reductions could potentially be achieved by converting manure management systems from high-CH4 emitting anaerobic lagoons to alternative management systems...."[71]

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[62] Plant G, Kort EA, Brandt AR, Chen Y, Fordice G, Gorchov Negron AM, Schwietzke S, Smith M, Zavala-Araiza D. Inefficient and unlit natural gas flares both emit large quantities of methane. Science. 2022 Sep 30;377(6614):1566-1571. doi: 10.1126/science.abq0385. Epub 2022 Sep 29. PMID: 36173866.https://www.triplepundit.com/story/2022/gas-flaring-methane/756386

[63] Duren, Riley, and Deborah Gordon. "Tackling unlit and inefficient gas flaring." *Science* 377, no. 6614 (2022): 1486-1487.

[64] Huang K, Fu JS. A global gas flaring black carbon emission rate dataset from 1994 to 2012. Sci Data. 2016 Nov 22;3:160104. doi: 10.1038/sdata.2016.104. PMID: 27874852; PMCID: PMC5127487.

[65] https://settje.com/news/2021/10/21/the-benefits-of-manure-aeration-systems/#:~:text=As%20referenced%20above%2C%20the%20aeration,%2C%20and%20K)%20remains%20undiluted.

[66] https://www.cdfa.ca.gov/oefi/AMMP/docs/ListofAMMPPractices.pdf

[67] Ibid.

[68] Ibid.

[69] Kaffka, S.; Barzee, T.; El-Mashad, H.; Williams, R.; Zicari, S.; Zhang, R. Evaluation of Dairy Manure Management Practices for Greenhouse Gas Emissions Mitigation in California, 2016. Final Technical Report to the State of California Air Resources Board. Available online: https://biomass.ucdavis.edu/wp-content/uploads/ARB-Report-Final-Draft-Transmittal-Feb-26-2016.pdf

[70] Harrison, Brendan P., Si Gao, Melinda Gonzales, Touyee Thao, Elena Bischak, Teamrat Afewerki Ghezzehei, Asmeret Asefaw Berhe, Gerardo Diaz, and Rebecca A. Ryals. "Dairy manure co-composting with wood biochar plays a critical role in meeting global methane goals." *Environmental science & technology* 56, no. 15 (2022): 10987-10996.

[71] Pressman, Eleanor M., Shule Liu, and Frank M. Mitloehner. "Methane emissions from California dairies estimated using novel climate metric Global Warming Potential Star show improved agreement with modeled warming dynamics." *Frontiers in Sustainable Food Systems* 6 (2023): 1072805.

5. Vermifiltration, which uses worms to filter and aerate liquid manure, is as effective as digesters in capturing methane.[72] A 2022 study of a commercially available[73] product on a central California dairy farm showed very extensive reduction of methane and nitrous oxide from dairy wastewater. “Vermifiltration reduced methane emissions relative to an anaerobic lagoon by 97–99% and removed 87% of the volatile solids, contaminants such as salts and trace elements, P (83%) and N (84%) from the wastewater.”[74] Vermifiltration can be used prior to flushing waste to a lagoon.
6. Lagoon additives were evaluated by UC Davis professors: “Adding biochar, acids, and straw to manure could mitigate CH4 emissions by 82.4%, 78.1%, and 47.7%, respectively. However, the data for straw is quite small so it should not be taken out of context as it may introduce a source of carbon into lagoons. The meta- analysis conducted with selected additives indicated manure additives were an effective method to reduce CH4 emission, with biochar being the most effective.”[75]
7. A commercial additive, SOP LAGOON, has been tested by UC Davis as a method to abate not only methane but ammonia, nitrous oxide and CO2. “Results showed that SOP LAGOON applied at the high dose (61.6 g of SOP LAGOON per m3 of manure) versus the control greatly reduced ($p < 0.05$) emissions of CO2, CH4, N2O and NH3 by 14.7%, 22.7%, 45.4% and 45.9%, respectively. Furthermore, the high dose of SOP LAGOON treated samples versus the control samples showed less odor intensity ($p < 0.05$).”[76]
8. Dairy farms in Europe use acidification to control ammonia but it also strongly abates methane. This is likely an option only if farmers capture the dairy slurry and store it in covered containers instead of using flush/lagoon methods.[77] However, Jaffe, reports that 40% of the California dairy herd does not use lagoons.[78] A 2021 Canadian study found optimum amounts of sulfuric acid to add to slurry in containers.[79] “Self-acidification,” which is less toxic, is also possible and in experiments has shown over 70% reduction of methane in slurry in containers.[80] (The manure has brewers sugar added to it which

[72] A number of presentations on vermifiltration are available at: https://lpelc.org/use-of-vermifiltration-as-a-tool-for-manure-management/

[73] https://biofiltro.com

[74] Dore, Sabina, Steven J. Deverel, and Nicholas Christen. "A vermifiltration system for low methane emissions and high nutrient removal at a California dairy." *Bioresource Technology Reports* 18 (2022): 101044. https://www.sciencedirect.com/science/article/pii/S2589014X22001013

[75] Kebreab, Ermias, and Xiaoyu Feng. "Strategies to reduce methane emissions from enteric and lagoon sources." *Contract 17RD018* (2021): 57.

[76] Peterson, Carlyn B., Hamed M. El Mashad, Yongjing Zhao, Yuee Pan, and Frank M. Mitloehner. "Effects of SOP lagoon additive on gaseous emissions from stored liquid dairy manure." *Sustainability* 12, no. 4 (2020): 1393.

[77] Kupper, Thomas, Christoph Häni, Albrecht Neftel, Chris Kincaid, Marcel Bühler, Barbara Amon, and Andrew VanderZaag. "Ammonia and greenhouse gas emissions from slurry storage-A review." *Agriculture, ecosystems & environment* 300 (2020): 106963; and, especially, Petersen, Søren O. "Greenhouse gas emissions from liquid dairy manure: Prediction and mitigation." *Journal of dairy science* 101, no. 7 (2018): 6642-6654. https://www.sciencedirect.com/science/article/pii/S0022030217311165

[78] Jaffe, Amy Myers, Rosa Dominguez-Faus, Nathan Parker, Daniel Scheitrum, Justin Wilcock, and Marshall Miller. "The feasibility of renewable natural gas as a large-scale, low carbon substitute." *California Air Resources Board Final Draft Report Contract* 13-307 (2016).

[79] Sokolov, Vera, Jemaneh Habtewold, Andrew VanderZaag, Kari Dunfield, Edward Gregorich, Claudia Wagner-Riddle, Jason J. Venkiteswaran, and Robert Gordon. "Response Curves for Ammonia and Methane Emissions from Stored Liquid Manure Receiving Low Rates of Sulfuric Acid." *Frontiers in Sustainable Food Systems* 5 (2021): 224.

[80] See: Bastami, Mohd Saufi B., Davey L. Jones, and David R. Chadwick. "Reduction of methane emission during slurry storage by the addition of effective microorganisms and excessive carbon source

results in lactic acid.) Acidification can be done automatically in the barn as well as in storage tanks and possibly lagoons: "the potential for mitigation of CH_4 emissions from manure through in-barn acidification may be 9-12% in temperate climates."[81]

9. Covering manure compost piles can greatly reduce GHG emissions, and mixing in biochar can reduce emissions by 79%.[82] And lagoons can be covered with biofilters that remove methane.[83]

APPENDIX C: Abatement Methods – Enteric Emissions

Nearly 20 percent of the State's methane emissions come from enteric fermentation (mostly belching) of dairy cows, and another ten percent comes from enteric fermentation of non-dairy livestock (primarily other cattle).

The California budget of 2023 contains $25 million for a pilot program of enteric emission reductions to "encourage the voluntary use of products or strategies, such as feed additives, that are scientifically proven and safe for enteric emissions reductions in the state's livestock sectors."

In *Meeting the Call,* the CLEAR Center points out that there are already options for using feed additives to reduce enteric methane even though FDA approval of the best studied additive, 3-NOP, is not expected for one to three years. 3-NOP is likely to reduce methane by 20 to 40% Here are other leading candidates:[84]

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from brewing sugar." *Journal of environmental quality* 45, no. 6 (2016): 2016-2022; and Sokolov, Vera, Andrew VanderZaag, Jermaneh Habtewold, Kari Dunfield, Claudia Wagner-Riddle, Jason J. Venkiteswaran, and Robert Gordon. "Greenhouse gas mitigation through dairy manure acidification." *Journal of environmental quality* 48, no. 5 (2019): 1435-1443. Prado, Joana, João Chieppe, Anabela Raymundo, and David Fangueiro. "Bio-acidification and enhanced crusting as an alternative to sulphuric acid addition to slurry to mitigate ammonia and greenhouse gases emissions during short term storage." *Journal of Cleaner Production* 263 (2020): 121443.

[50] Petersen, Søren O. "Greenhouse gas emissions from liquid dairy manure: Prediction and mitigation." *Journal of dairy science* 101, no. 7 (2018): 6642-6654.

[82] Chadwick, D. R. "Emissions of ammonia, nitrous oxide and methane from cattle manure heaps: effect of compaction and covering." *Atmospheric environment* 39, no. 4 (2005): 787-799; Hansen, Martin N., Kaj Henriksen, and Sven G. Sommer. "Observations of production and emission of greenhouse gases and ammonia during storage of solids separated from pig slurry: effects of covering." *Atmospheric Environment* 40, no. 22 (2006): 4172-4181. Harrison, Brendan, Zeyi Moo, Evelyn Perez-Agredano, Si Gao, Xuan Zhang, and Rebecca Ryals. "Biochar-composting substantially reduces methane and air pollutant emissions from dairy manure." *Environmental Research Letters* (2024).

[83] Pratt, Chris, Adrian S. Walcroft, Kevin R. Tate, Des J. Ross, Réal Roy, Melissa Hills Reid, and Patricia W. Veiga. "Biofiltration of methane emissions from a dairy farm effluent pond." *Agriculture, ecosystems & environment* 152 (2012): 33-39.

[84] Dillon, Jasmine A., Kim R. Stackhouse-Lawson, Greg J. Thoma, Stacey A. Gunter, C. Alan Rotz, Ermias Kebreab, David G. Riley et al. "Current state of enteric methane and the carbon footprint of beef and dairy cattle in the United States." *Animal Frontiers* 11, no. 4 (2021): 57-68.

- Mootral Ruminant is made from natural sources (garlic, citrus extract) and maybe able to reduce methane by 20%. It is commercially available and would be easy to scale up.[85]
- Agolin Ruminant is commercially available, and the FDA classes it as Generally Recognized as safe. It may reduce methane by around 10%. It has been used by over a million cows, 250,000 in the US.[86]
- Asparagopsis Taxiformis is a seaweed that has shown reductions in enteric methane by as much as 98%.[87] A study on a California dairy showed a reduction of 52%.[88] In 2022 the California Department of Food and Agriculture approved a product called Brominata, a red seaweed, as a "digestive aid," clearing the way for it to be used as an additive for its methane reduction properties.

CARB and CDFA can use the $25 million to mount a large-scale pilot that will provide much valuable information for regulation, if it becomes necessary. However, additional research may be required for some of these agents. For example, Agolin trials have lasted for five months at the most.[89]

There are other technologies being developed that may be useful. For example, catalytic biofilters can capture methane in the air at percentages as low as 5%. In trials they have been installed over feed troughs in dairies to capture enteric methane.[90]

APPENDIX D: Funding Mechanisms

To implement adequate levels of methane abatement, a mechanism is necessary to ensure adequate funding of dairy digesters and other manure management methods through 2030 and beyond.

A. Current funding.

[85] 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

[86] A recent test of Agolin was performed at UCD found statistically significant reductions in methane per liter of milk and an overall (but not significant) reduction. Carrazco, Angelica V., Carlyn B. Peterson, Yongjing Zhao, Yuee Pan, John J. McGlone, Edward J. DePeters, and Frank M. Mitloehner. "The Impact of Essential Oil Feed Supplementation on Enteric Gas Emissions and Production Parameters from Dairy Cattle." *Sustainability* 12, no. 24 (2020): 10347. Another test found 6% less methane overall but 20% less methane per liter of milk. Hart, Kenton J., Hefin G. Jones, Kate E. Waddams, Hilary J. Worgan, Beatrice Zweifel, and C. Jamie Newbold. "An essential oil blend decreases methane emissions and increases milk yield in dairy cows." *Open Journal of Animal Sciences* 9, no. 03 (2019): 259.

[87] Kinley, Robert D., Gonzalo Martinez-Fernandez, Melissa K. Matthews, Rocky de Nys, Marie Magnusson, and Nigel W. Tomkins. "Mitigating the carbon footprint and improving productivity of ruminant livestock agriculture using a red seaweed." *Journal of Cleaner production* 259 (2020): 120836.

[88] Audrey Schmitz, "Red seaweed supplement achieves 52 percent methane reduction," Progressive Dairy, February 7, 2022.

[89] Personal correspondence with Peter Williams, Agolin representative.

[90] Pratt, Chris, and Kevin Tate. "Mitigating methane: emerging technologies to combat climate change's second leading contributor." *Environmental science & technology* 52, no. 11 (2018): 6084-6097.

As noted, incentive funding for reduction of livestock methane should be unnecessary as all industries except agriculture are required to abate their greenhouse gas emissions. In SB 1383 State of California decided that agriculture is a partial exception – whether because of the value of the product to consumers, the marginal earnings and uncertainty of the industry, the history of government support going back to the first Farm Bill in 1933, or to the effective lobbying of a concentrated industry. In any case, digesters and many of the other manure management methods listed above are expensive, up to five million dollars per farm. Were such measures mandated with no financial incentives, dairies would not – indeed could not[91] – pass the costs on to their customers. So some degree of government support is necessary. The question becomes how much of an incentive and how it is provided in conjunction with regulations to ensure that all dairies are abating methane.

There are currently four main sources of incentive financing: A small amount of cap-and-trade funds for digesters, the Low Carbon Fuel Standard and its federal counterpart, the Dairy Digester Research and Development Program, and the Alternative Manure Management Program. Each of these approaches, and in combination, has significant problems as a funding mechanism:

- *Cap and Trade.* Digesters have been incentivized from 2008 through the Cap-and-Trade offset program. Between 2008 and 2020 a total of 4,966,638 credits were issued, which is putatively equivalent to reductions of that many tons of CO_2e, as each credit is worth a metric ton of CO2. However, a recent study found that digesters funded through cap and trade did not produce additionality in 80% of the grants. That is, the digesters existed already and just used cap and trade funds as supplementary income.[92]
- *Low Carbon Fuel Standard.* Cap and Trade funds have largely been replaced by LCFS payments because prices for dairies are much higher:

  > "In nominal (i.e., unadjusted for inflation) terms, LCFS prices doubled over a 2-year period, from less than \$100/MT CO_2e at the end of 2017 to over \$200/MT CO_2e by the beginning of 2020. In 2018, 79% of digesters used biogas to produce electricity or heat/power. Due to high LCFS prices, 94% of digesters established during the next 5 years used biogas to produce CNG."[93]

  According to UC Davis agricultural economist Aaron Smith, the LCFS overvalues the "avoided emissions" from dairies it incentivizes by a large amount.[94] And LCFS affects only 113 dairies, about half of which are in other states.[95] In workshops over the last year commenters have pointed out numerous unintended consequences of the very high "avoided emissions credit," including:

  a. Dairies using alternative manure management methods of abatement are put at a financial disadvantage as are small dairies that cannot use digesters.

[91] Dairies are price takers. That is, they cannot affect the market price of their product. https://www.ecosystemmarketplace.com/articles/payments-performance-can-help-california-dairy-farmers-meet-new-methane-requirements/

[92] Pierce, M. Hanna, and Aaron L. Strong. "An evaluation of New York state livestock carbon offset projects under California's cap and trade program." *Carbon Management* (2023): 2211946.

[93] Pierce, M. Hanna, and Aaron L. Strong. "An evaluation of New York state livestock carbon offset projects under California's cap and trade program." *Carbon Management* (2023): 2211946.

[94] https://asmith.ucdavis.edu/news/revisiting-value-dairy-cow-manure

[95] Only 58 dairies participating in the LCFS are located in California. The alternative fuel type produced for 48 of the 58 is compressed natural gas; 9 produce electricity; and 1 produces hydrogen. The key figure is that only 58 California dairies are currently enrolled in the LCFS program and receiving the very low carbon intensity score afforded by the "Avoided Emissions" category.

b. LCFS payments provide most profits to the largest dairies, incentivizing further concentration.[96]
c. The very high credit for a combustion fuel works against policy oriented to zero-emission vehicles. LCFS staff have proposed phasing out the avoided emissions credits in 2040 in recognition that it distorts policy promoting electrification of transportation.
d. LCFS is intended to decarbonize transportation fuels, but the excessive payments to dairies is distorting agricultural methane policy as its existence works against regulation.
e. Because biomethane from digesters is sold to natural gas companies it reduces the impetus to eliminate fossil (natural) gas as it is claimed to be "renewable" although it makes up only a small proportion of gas sold.
f. "Book and claim" using avoided emissions produces some mind-bending results when applied to hydrogen. A company that steam reforms hydrogen from natural gas can buy avoided emission credits that provide almost twice the value that LCFS accords actual green hydrogen from electrolysis; it is also far more than the US government is offering for green hydrogen through the Inflation Reduction Act.[97]

- The BioMAT program incentivizes several biomass feedstocks, including dairy methane, and requires electrical utilities to purchase electricity from them. The amounts are relatively small. Double counting of emissions is theoretically a problem with this program as well.
- The federal Renewable Fuel Standard (RFS) program can be added to the LCFS.
- The DDRDP and AMMP are reasonable approaches but result in uncertain and unmonitored methane reductions. Statements made on the application form are not verified or monitored. And each program has served a relatively small number of dairies. Approximately 1,000 of 1,400 dairies are not enrolled in any methane mitigation program.
- Another current source of funding is earnings from products created from manure – an organic substitute for synthetic fertilizer, bedding and compost primary among them.[98] And the electricity and heat created by digesters has value on the farm itself.
- Finally, there are numerous other state and federal programs that can be tapped for digester funding in particular, including the EQIP and the Rural Energy for America federal programs, the Aliso Canyon Mitigation Agreement, and the California Energy Commission's Natural Gas Research and Development program.

Nonetheless, digesters and many AMMP projects cost millions of dollars, so a stable source of funding is required.

B. Proposed funding

We propose as an alternative/supplement to these grant and fuels programs that California pay for performance, that is, pay on an ongoing basis for verified reductions in methane that ensure

[96] A. Younes and K. Fingerman, "Quantification of Dairy Farm Subsidies Under California's Low Carbon Fuel Standard, Arcata, CA." Study conducted for the Union of Concerned Scientists.(2021).
[97] Nikita Pavlenka. *Gray, blue, or moo hydrogen? How gas companies are milking California's LCFS.* International Council on Clean Transportation. https://theicct.org/lcfs-hydrogen-crediting-jun23/
[98] The 2017 SLCP Strategy says: "CalRecycle, CDFA, and other agencies are working together to support healthy soils through composting and building markets for soil amendment products in the State."

additionality. Such an approach is fair, since it offers the payments to any dairy that achieves reductions. It also removes much of the uncertainty about what public funds buy.

Regulations would require each dairy to produce a minimum amount of reductions from measures listed above, such as covering lagoons, composting, using biochar, or acidification of small lagoons or slurry. Certified reductions *above* the minimum would receive support. If this were embedded in law, the state would be required to assure adequate funding, perhaps by establishing a Methane Reduction Fund.

The most direct method to assure funding would be for the Governor to propose and the Legislature enact a tax on milk and meat products, dedicating the revenues for abating methane and other pollutants attributable to the livestock and dairy industries. This would have the added benefit of setting the price of dairy products to a real level; that is, the price would no longer externalize climate and pollution costs. This in turn might reduce demand for dairy products, which is ultimately needed.

There are a variety of other financing possibilities. SB 1383 required CARB report on a Pilot Funding Mechanism;[99] the report contains a number of ideas that have not been tried. The federal government also has cost-sharing programs for digesters, namely the USDA Natural Resources Conservation Service (NRCS) Environmental Quality Incentives Program (EQIP).[100] These might serve as a model. Funds for methane abatement might also be put into the upcoming Climate Bond.

A novel approach proposed by Jeremy Martin of the Union of Concerned Scientists is to divert the LCFS credits for avoided methane to a new non-profit organization that would use the funds for agricultural methane abatement.[101]

Finally, adding dairies and other livestock facilities to cap and trade or actually creating an agricultural specific carbon market is a possibility.[102] Dairies are actively planning to create a carbon market from reduced enteric methane emissions once 3-NOP is approved for use.

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[99] https://ww2.arb.ca.gov/sites/default/files/2020-07/sb1383_financial_pilot_mechanism_whitepaper.pdf
[100] https://www.epa.gov/sites/default/files/2014-12/documents/funding_digestion.pdf
[101] April 8, 2022 letter to Matthew Botill, Chief, Industrial Strategies Division California Air Resources Board from Jeremy Martin, Union of Concerned Scientists.
[102] Lewandrowski, Jan, and Kathryn Zook. "GHG Mitigation in the absence of a National Carbon Market." *Choices*30, no. 2 (2015): 1-6; and De Cara, Stéphane, Martin Houzé, and Pierre-Alain Jayet. "Methane and nitrous oxide emissions from agriculture in the EU: a spatial assessment of sources and abatement costs." *Environmental and Resource Economics* 32 (2005): 551-583.