Tackling Climate Change through

Agricultural Methane Emissions Reduction

Final Report

CE 105
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1

Team mission statement

We want to explore strategies to reduce agricultural methane emissions in California so as to adhere to 1.5 degree warming pathways, through simultaneous policy as well as individual action through education and advocacy. In completing this task, we want to prioritize equity, environmental justice, and human health.

Table of Contents

Introduction

California for many decades has been known as the “Land of Milk and Honey.” To an average consumer of milk and honey, this may seem like a great title; a title that reflects fruitfulness and prosperity. California provides vast amounts of fruits, vegetables, and nuts to the entire continental United States (“Crops Grown in California | Fruit Growers Supply Blog” n.d.). California as a state would be the fifth largest economy in the world, with the agriculture sector being a large contributor (“If California Were A Country - Bull Oak Capital” n.d.). The land having an abundance of milk and honey does not come without consequences. To produce all these agricultural products at such a consistently high rate, California has to invest in large facilities that emit large amounts of pollutants into the atmosphere.

California is our country’s number one dairy producer, so it comes as no surprise that it releases large amounts of emissions to keep up with daily operations. One of the primary emissions stemming from that sector is methane, a short lived climate pollutant and precursor ground level ozone, a toxic respiratory irritant.

Climate change has long been a threat to the livelihood of humans as well as animals, even dating back to the pre-industrial period between 1850 and 1900 ("Global Warming vs. Climate Change | Resources – Climate Change: Vital Signs of the Planet" n.d.). Although much climate change action has historically been focused on carbon dioxide emissions, short-lived climate pollutants (SLCPs) are an increasingly important consideration in climate action and need to be reduced at the same time we tackle carbon emissions. Methane (CH_4) — although it has a much shorter lifetime in the atmosphere than carbon, only about 12 years — is over 80 times as potent in global warming potential over 20 years, and about 28 times as potent over 100 years. In fact, since 1984, we have seen a sharp increase in methane emissions and, if enough isn't done to reduce greenhouse gas emissions by 2030, the effects of climate change will be irreversible and the most vulnerable populations will be hit the hardest. Figure 1 below shows the global share of methane in the atmosphere over time: the steep increase the curve presents is a cause for concern.

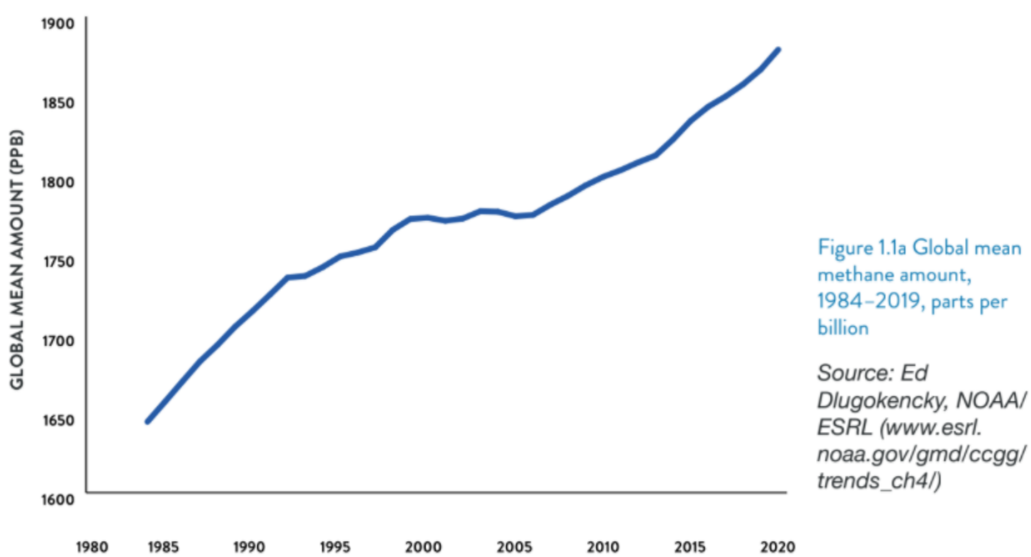

Figure 1: *Global Mean Methane Amount, 1984 - 2019 (ppb):* As evident from the graph, the increase in methane emissions has continued in recent years. Source**:** ("Global Monitoring Laboratory - Carbon Cycle Greenhouse Gases" n.d.)

Methane's 12 year atmospheric residence time means if we act now, we will see short term results. The single fastest pathway to adhering global warming below 1.5

degrees celsius is through significant methane reduction. Therefore, it is vital that methane emissions begin to have more stringent regulations, as there is potential to curb warming by as much as 0.5 degrees celsius. Only recently have global leaders been more explicit in the need to focus on methane reduction, with the Global Methane Pledge being enacted in late 2021. A major problem is that there is less awareness of methane as a greenhouse gas, and therefore less action to reduce it. (GMA 2021) Because livestock farming contributes to a significant portion of methane emissions, action must be taken in the agricultural sector in order to see the emission reductions in line with 1.5° degree warming pathways.

In addition to climate change mitigation, there are additional benefits to curbing methane emissions. When looking at the potential benefits of every million tonnes (Mt) of methane reduced, we prevent 1430 premature deaths due to ozone; we avoid losses of 145000 tons of various crops and of around 400 million hours of labor due to extreme heat. For each *tonne* of methane reduced, we reap a monetary benefit of US $4300 for both market and non-market impacts. (GMA 2021)

Current measures that specifically target methane, combined with measures that tackle carbon emissions as a whole can reduce global methane emissions by 45% (or 180 Mt/year) by 2030, with 15% of that coming from measures such as reducing food waste and switching to renewable energy. This translates to a reduction of 0.3° C over the next two decades. (GMA 2021)

Our Vision for 2027 and Beyond

In the preferred state in 2027, California will have reduced its total methane emissions by 40%. The values emphasized in our preferred state would be centered around cultural and behavioral shifts. In addition, a big component of reducing total methane emissions will lie in changes to agricultural practices and food systems. Methane reduction will be a larger priority in production and consumption. Additionally, there will be infrastructure and policy in place to help incentivize this shift. Additionally, local educational programs will perpetuate a waste-conscious landscape in which consumers are conscious of their consumption, what its environmental impacts are, and how to discard remnants.

Currently, a lot of policy centered around methane emitted from the agriculture sector is voluntary and incentive based. Instead, we envision policies equipped with funding via loan/grant availability, education for dairy farmers, and robust state support at all aspects of the implementation process. An example could be requiring digesters and methane harvesting for biogas in order to turn a profit that would help the farmers in the long run, as now they have an additional product to sell to consumers.

Education on composting as well as food systems would be implemented in K-12 curriculums. Reduce, Reuse, Recycle, and now Rot, would be taught in order to be transformed into common knowledge. In addition, ruminant livestock product consumption statewide would be decreased through the wider availability of delicious and culturally sensitive plant-based meals (meals containing no animal products, such as beef or dairy) at K-12 schools. While industry changes and policy should be the driving action behind emission reduction, a future in which individuals are more educated on the environmental impacts of their diet and reduce red meat demand as a result is also a key feature of the preferred state.

Key Areas of Concern

Globally, the agricultural sector accounts for around 40% of total methane emissions. Rice cultivation comprises 8% whereas livestock agriculture, broken down into enteric fermentation, in which digestive processes of cows and other animals result in methane releases in farts or belches, as well as methane release from stored manure, comprises 32% of total methane emissions. Ruminant livestock account for around 115 Mt/year of emissions, while rice cultivation accounts for around 30 Mt/year. While rice production is expected to remain stable, ruminant emissions are currently projected to increase as more affluent people in the world demand more meat, resulting in more livestock. California is the number one dairy producer in the United States, therefore strides to improve the emissions in this industry are of special concern. (GMA 2021)

In Figure 2 below, locations of dairies and digesters in California in 2019 are mapped. The sheer scale of dairies, of which there are over a thousand, shows just how many potential sources of agricultural methane there are. Digesters capture methane and allow it to be used as a biogas. While there are some digesters in the state of California, represented by the green rectangles, it is clear that this technology needs to be drastically scaled up in order to capture and convert more methane into biogas.

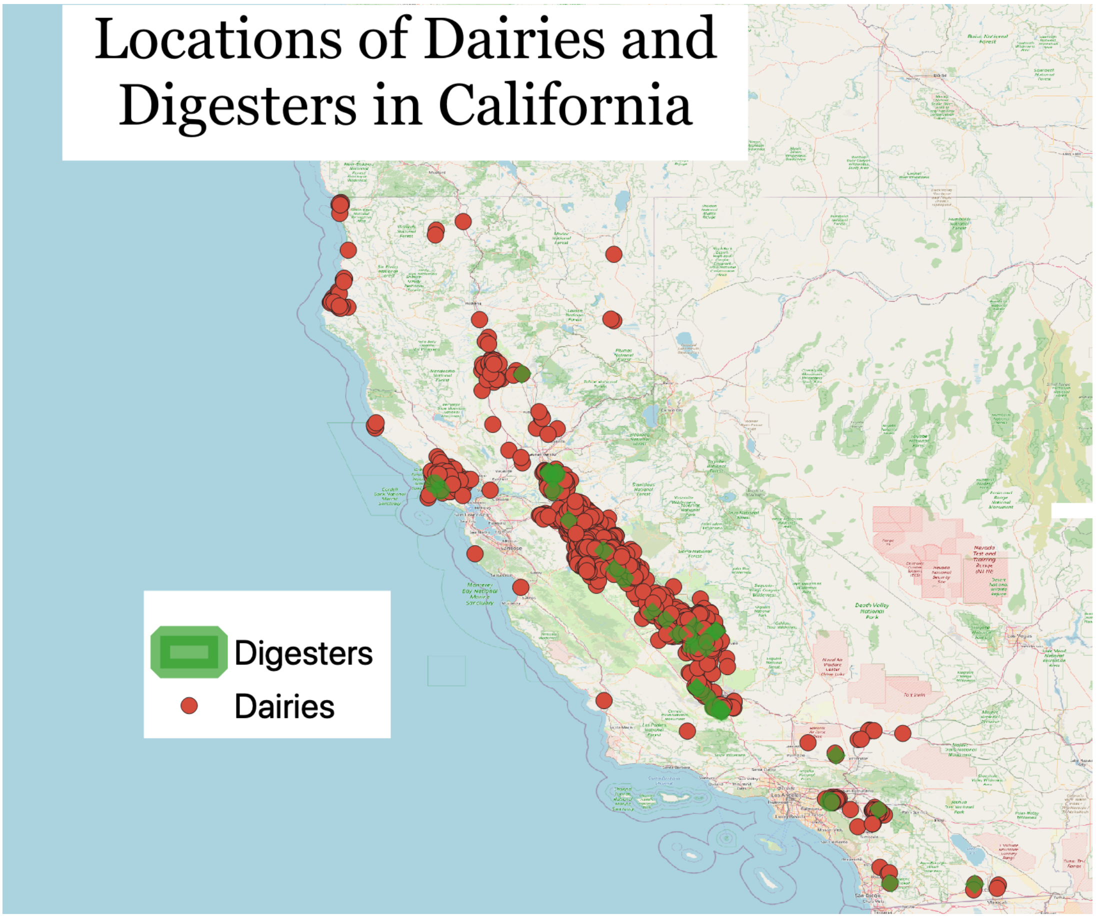

Figure 2. Map showing locations of dairies and digesters in California in 2019. Data Source: North American Carbon Data.

While a lack of digesters is a component of the problem state, there are also tricky politics involved with digesters, as subsidies given to dairy farmers for biogas from digesters can disincentivize scaling down the dairy industry and create similar environmental justice issues as cap and trade policies (Charles 2022).

A root of many problems when it comes to SLCPs is that focus and narrative on climate change mitigation has been so focused on carbon dioxide that there is less awareness of the effects of methane. People are less likely to demand policies curbing methane emissions if they are not fully aware of the higher global warming potential and urgency of the emissions.

There have been recent efforts to reduce methane emissions with the enactment of SB 1383 in California, but the California Air Resources Board may not introduce regulations to achieve these methane goals for the agricultural industry until January 1, 2024 (CARB).

Our systems map (Figure 2) below illustrates the relationships at work in the system. As agricultural methane emissions increase, climate change worsens, and associated tropospheric ozone production leads to air pollution. As both of these increase, human health concerns increase. There is a leverage point opportunity to increase education on methane through campaigns (such as social media campaigns associated with the Global Methane Pledge, for example) and advocacy. Increased education can lead to a decrease in the demand for ruminant animal products, as people become more aware of the environmental impacts of red meat and dairy and may choose to prioritize more plant-based diets. In addition, these education efforts as well as an increase in health concerns can lead to a greater public awareness of methane and demand for action. As this awareness increases, governments will take more action to regulate agriculture. With more regulation and attention on this issue, this will lead to the development of better methane capture technologies and better agricultural practices overall. These developments in tandem with a decreased demand for livestock agriculture can both decrease agricultural methane emissions.

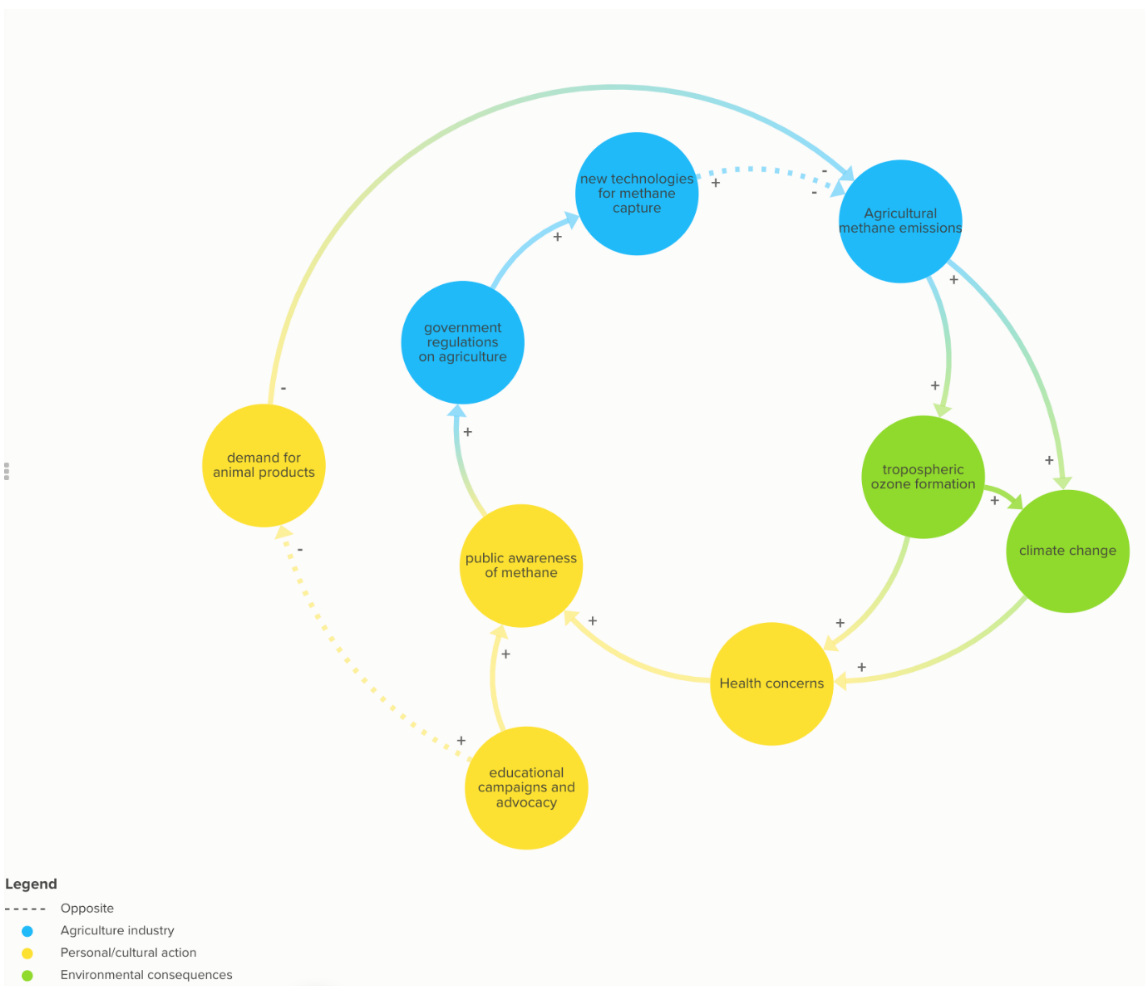

Figure 3. Systems map describing components of methane in the agricultural sector.
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Data Visualization and Analysis

Methane is a critical ozone precursor and the Central Valley of California has been an EPA designated nonattainment region regarding tropospheric ozone levels. Tropospheric ozone can be transported long distances via wind. Most methane emissions in Central Valley come from enteric fermentation and manure from ruminant livestock (not oil and gas as you may think). Heavy lobbying from the meat and dairy industry has resulted in minimal environmental restrictions on those industries.

According to a study conducted by Oliver Lazarus, Sonali McDermaid, and Jennifer Jacquet, from 2000 to 2019 industry lobby groups spent nearly $200 million to oppose climate and environmental regulations. As an example, the National Pork Producers Lobby went against a cap-and-trade bill which would have seized a large portion of land from pork farmers in order to convert cropland into forest (Lazarus, McDermid, and Jacquet 2021). Perhaps the largest instance of lobbying was seen during 2018 where there was widespread debate over the new Farm Bill. Otherwise known as the Agricultural Improvement Act of 2018, the Farm Bill is a five year, $867 billion attempt at, as the title suggests, improving the state of agriculture in the US. The Farm Bill funds various programs with focus on the livelihood of farmers, local food systems, soil and water management, and equal opportunity for all farmers ("What's in the 2018 Farm Bill? The Good, The Bad and The Offal…" 2018). This bill, however, is not without its faults .

For one, the Farm Bill fails to remove both high subsidies given to high-income farms as well as a loophole which allows non-working family members to file as the 'farm manager' in exchange for upwards of $125, 000 in government subsidies (A 501tax-exempt, NW, and Washington 2018). These are only two of many problems the Farm Bill does not address.

When it comes to what are known as 'mega-dairies', we know that there are a number of programs which exist solely to support them which are funded directly by the Farm Bill. One example of these programs would be the Environmental Quality Incentives Program which promotes the management of giant manure lagoons, stating only the benefits of keeping such large amounts of manure for fertilization and disregarding the harmful effects of methane emissions. Another example would be the Farm Service Agency which seeks to construct new mega-dairies as well as expand existing ones. At the same time, these mega-dairies are being supported through other programs which aim at providing cheap commodities such as animal feed ("Milking the Planet" n.d.).

As mentioned before with the Environmental Quality Incentives Program, many groups are hired by lobbyists to conduct research which focuses on downplaying the effects of agricultural emissions. One way they do this is by showing the emissions as a percent of total emissions. In 2012, the US agricultural emissions made up only 10% of total emissions in the US ("Figure 5 Total U.S. Greenhouse Gas Emissions by Sectors in 2012 (2)" n.d.), while a country like Brazil had a share of agricultural emissions of 37% ("FIGURE 8 Brazilian CO2 Emissions by Sector" n.d.). Putting them side by side would convince an average citizen that agricultural emissions are no problem, however, when looking at the emissions in raw amounts, we see that both countries, as of 2021, spew about 400 million tons of harmful pollutants into the atmosphere. These numbers do not include the emissions from third-party sources a lot of the time given that many operations choose not to include these values.

As noted in a study conducted by the Institute for Agriculture and Trade Policy, or IATP, "Zero out of the 13 [top dairy corporations globally] have committed to a clear and absolute reduction of emissions from their dairy supply chains or emissions from the animals themselves" ("Milking the Planet" n.d.). This of course also applies to farms in CA, where we see a frequent lack of information being disclosed as it is not required by law. Thus, with the lack of regulations as a result of what some may call political corruption, these mega-dairies and other large farms will only continue to grow.

It is clear that methane emissions have grown over time and have a clear connection to agriculture involving livestock, so an alarming part of the present state is that production of these animal products is still currently growing. Figure 4 below charts the U.S. production of red meat in the last forty years, which continues to increase as more affluent people demand these food items.

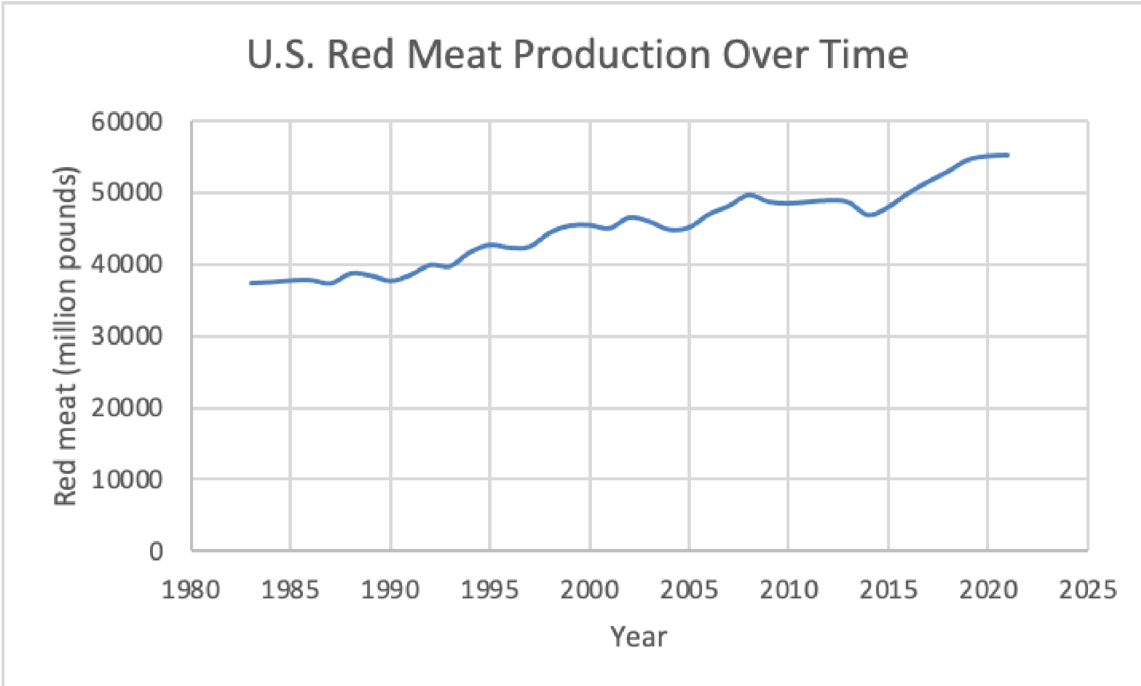

Figure 4: U.S. Red Meat Production over time. Source: USDA

From Figure 4 above, we can see that the US is eating more meat year after year. Given that California has an abundance of land suitable for farming, it takes on the task of creating and exporting large amounts of meat. This tremendous growth of production in this sector brings forth the troubling rise of concentrated animal feeding operations, or CAFOs. According to the US Environmental Protection Agency (EPA) a CAFO is defined as having at least 1000 combined cattle and calves, all of which live off of diets heavy in antibiotics and remain indoors for weeks at a time (OW US EPA 2015). The figure below shows the rise of CAFOs in California since 1964 where the data for farms with over 1000 combined cattle and calves becomes available publicly:

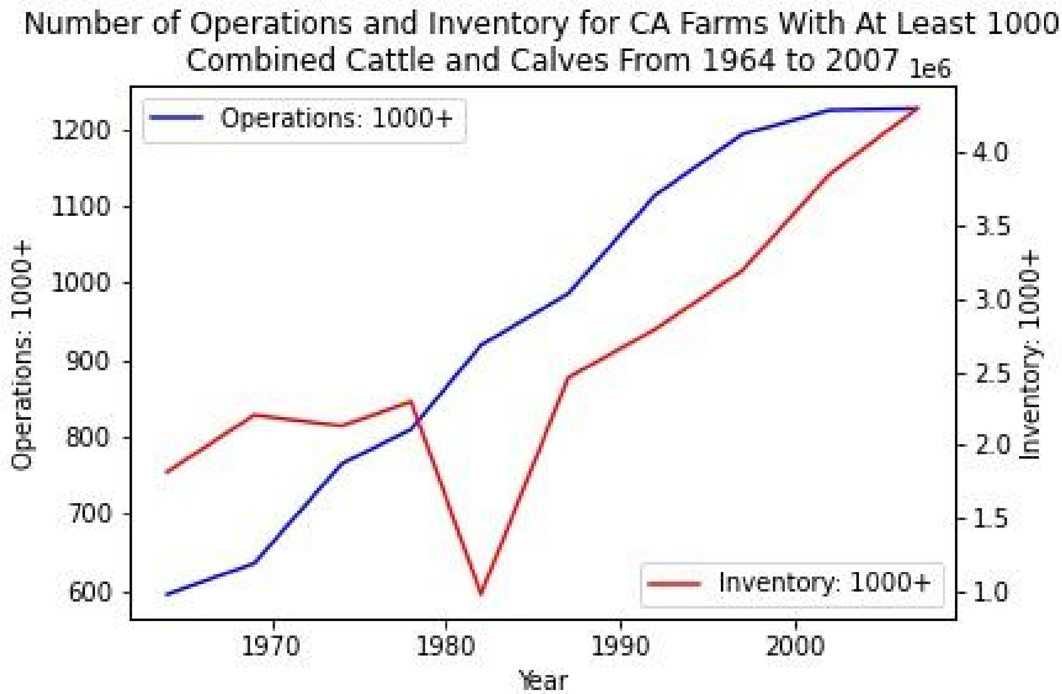

Figure 5: Graph showing the rise of both CAFOs and CAFO inventory. Both of these values have been steadily increasing since 1964, showing a shift to more heavily industrialized dairy and beef production in CA. To see a similar graph for operations with 500 or more cattle/calves, see Appendix. Source: ("USDA - National Agricultural Statistics Service - Census of Agriculture" n.d.)

In this graph we also see how the inventory (red line + right y-axis in millions) of combined cattle and calves essentially doubled between the years 1964 and 2007 going from 2 million to around 4.5 million total cattle and calves in California. The number of operations labeled as CAFOs (blue line + left y-axis) also doubled as it went from 600 CAFOs in 1964 to around 1,200 CAFOs in 2007.

Since 2007, there has been no new data for CAFOs available. However, there is data for slightly smaller farms which house 500+ combined cattle and calves. California has seen a reduction of nearly 350 farms of this magnitude while at the same time losing upwards of 200,000 total livestock. This could mean California is moving in the right direction, but it could also mean these farms are now much bigger and fall into a different category, so without more concrete figures, we cannot assume anything with much certainty. Of course other factors come into play such as how long these cows live and what their diets and lifestyles consist of.

As the prominence of CAFOs begins to dominate in the field of agricultural production, many smaller family-owned farms are out of business. This is due to the fact that these larger scale farms push out so much product that the price lowers, making it so the cost of the production exceeds the cost of selling ("The Disappearing Family Farm - Wild Farmlands Foundation" n.d.).

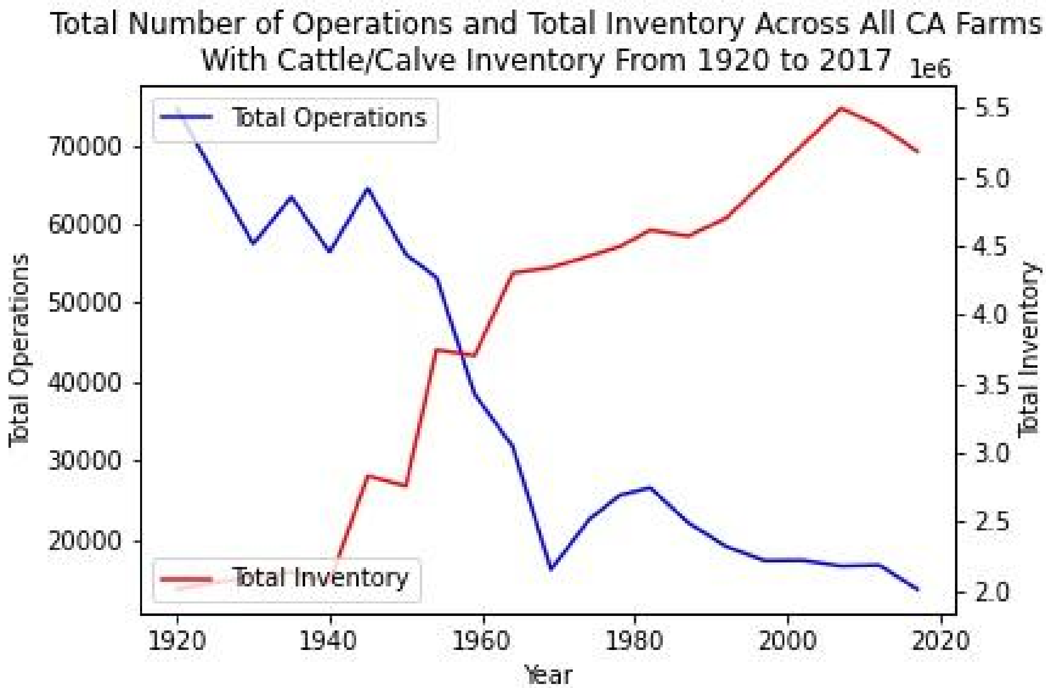

Figure 6: Graph showing the relationship between total operations and total inventory across all CA farms from 1920 to 2017. For a look at what this means in terms of percentages, see the Appendix. Source: USDA Agricultural Census 1920-2017 ("USDA - National Agricultural Statistics Service - Census of Agriculture" n.d.)

Evidently, the number of total operations across California (blue line + left y-axis) shrinks dramatically from 1920 to 2017, going from around 75,000 total operations to a measly 14,000 total farms. One would think that the amount of cattle would decrease as well since we lose around 60,000 total farms, but we instead see the total number of cattle (red line + right y-axis in millions) go from 2 million to more than 5 million total cattle! These trends can only be explained by the presence of these extremely large cattle operations. Some quick math (total cattle divided by total farms in California) tells us that in 1920 California farms had an average of about 27 cattle per farm. This number jumps to above 350 cattle per farm in 2017.

As the number of operations decreases by more than a factor of 3, the total amount of cattle and calves being housed in California farms almost triples. This increase in inventory is due in large part to innovations in medicine and technology which was brought forth by higher demand for dairy products ("16 Animal AgTech Innovators Transforming the Livestock Industry" 2020). For a farmer, it makes more sense to focus on one source of income rather than diversifying, thus a larger emphasis is placed on large investments in order to make even larger profit. This is yet another reason for the tendency of farmers to grow their operations as much as possible.

The consequences of maintaining such large amounts of cattle at once are detrimental to the livelihood of our environment however, with each operation being responsible for dumping large amounts of manure into large 'lagoons' as well as spewing harmful pollutants into the air via their use of heavy machinery.

In California, methane point-source emissions are dominated by landfills, which account for 41 percent; followed by dairies, which account for 26 percent; and the oil and gas sector, which is 26 per cent (Duren). Figure 7 below maps dairy-related methane plume sources for the year 2016-2017, showing higher rates of methane release in the Central Valley, where a higher concentration of dairies are located, as was established in Figure 2. This illustrates the existence of a methane problem related to manure management and digesters, but it is difficult to quantify as this satellite data is captured during a particular flight and does not measure emissions over time, and the point sources cannot be necessarily traced to a particular farm.

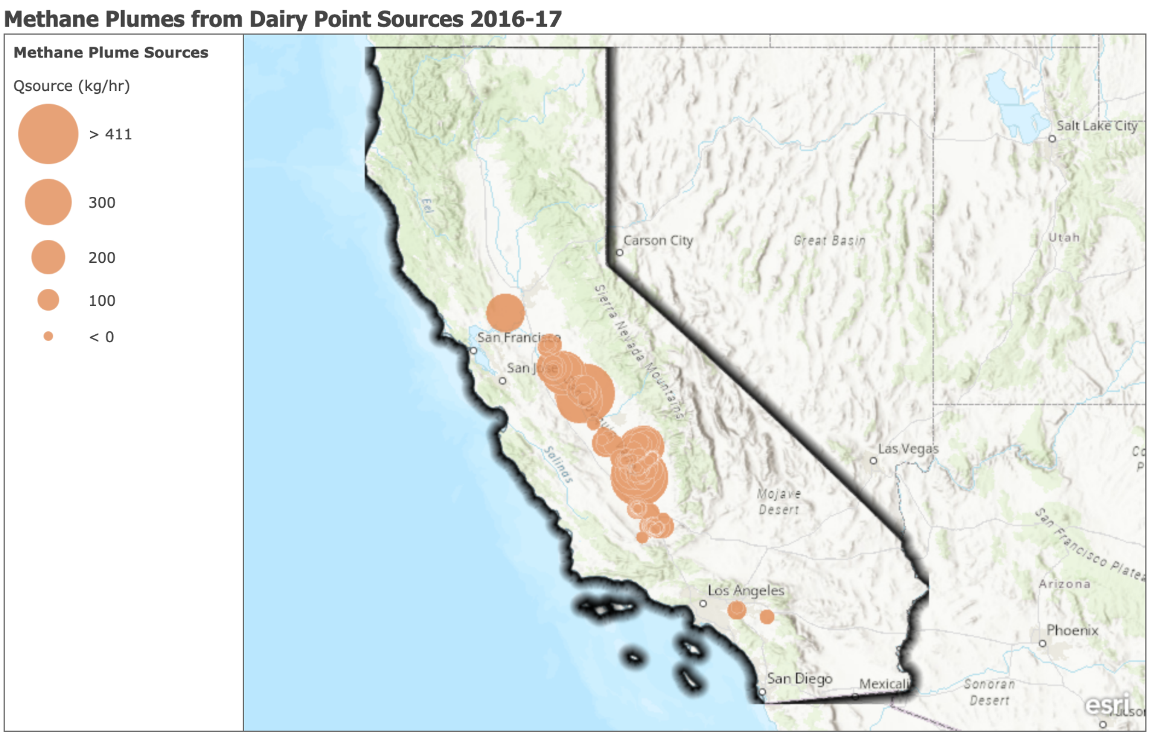

Figure 7. Dairy-related point sources of methane emission plumes. Source: Carbon Mapper

Looking at this satellite dataset, which was drawn from Carbon Mapper, we mapped each coordinate point identified as a source ID and evaluated the surrounding landmarks, making note of the nearest dairy farm. For many of these sources, there were multiple dairy farms nearby, or in some cases, no obvious sources in proximity. This geographical ambiguity, as well as factors such as wind, make it difficult to pinpoint individual perpetrators of plumes. The lack of usable data in this industry, as well as the lack of regulations requiring farms to track their emissions, are dominant problems of the present state.

Another dominant problem of the present state is a lack of robust anaerobic digestion integration. Anaerobic digestion is slowly being integrated into the dairy industry and the infrastructure surrounding the life cycle of manure. There are a variety of anaerobic digestion technologies that are available including small-scale digesters, anaerobic lagoons, plug-flow digesters, complete mix digesters and advanced digesters. Plug and flow digesters are the most commonly utilized technology in the dairy industry making up around 35% of digesters processing 260,000 dairy cattle at around 90 anaerobic digestion sites in California. Small-scale digesters can be utilized onsite on small-scale farms to create their own power and save money or sell their biogas and make more profits. It has a return investment of 4-7 years (Global Methane Initiative). The Global Methane Initiative has been taking steps in gathering data and resources about anaerobic digestion as has the California Department of Food and Agriculture. With support from programs and initiatives, it is becoming increasingly popular for a third party company to develop and operate anaerobic digestion systems that process manure from multiple farms. Shown in Figure 8 below, we see a high concentration of anaerobic digestion sites where there are dairy farms. Utilizing maps like this can help target and prioritize communities and regions in which anaerobic digestion should be implemented first. Since this is an urgent matter, tackling areas that are seeing high concentrations of emissions and cattle farms could be a great place to root a state-wide infrastructure.

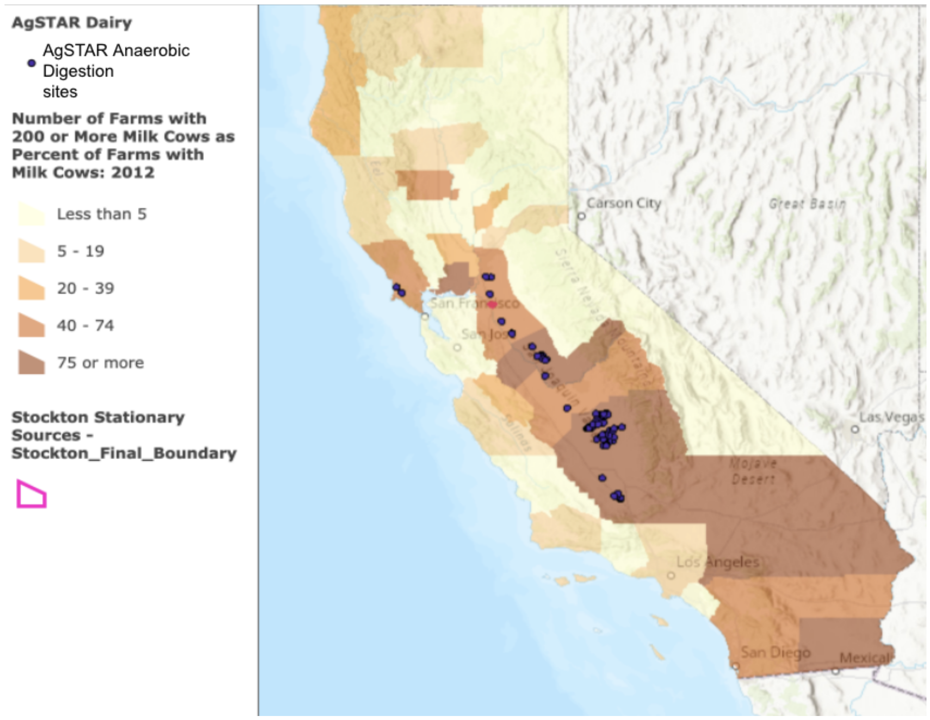

Figure 8: Dairy Farm concentration and anaerobic digester sites in California.Source: AgSTAR

As stated above, a centralized, hub-and-spoke system is being adopted naturally as we see a high frequency of high density cattle population. Dairy farms are approximately 95% family owned and managed with most part of larger producer cooperatives which are jointly owned by member farms. We see a high dairy and anaerobic digester population in the San Joaquin Valley with high density pockets south of Fresno. Even though we see high anaerobic digester integration in the south end of the San Joaquin Valley, areas such as Stockton have not been beneficiaries of the technology's abilities to reduce methane pollution.

California's current efforts for incentivizing manure anaerobic digestion are mainly two programs run by the Department of Food and Agriculture: Dairy Digester Research and Development Program and the Alternative Manure Management Program. The Alternative Manure Management Program is expected to reduce greenhouse gas emissions by an estimated 1.1 MMT CO_2e over the next 5 years. While these programs are tremendously helpful in integrating sustainable agricultural practices, the demand for funding is way higher than current available funds with over one half of applicants to these programs being rejected. There is a demand for anaerobic digestion to be integrated into agricultural practices but often high initial costs incentivize farmers to purchase the system on their own. Furthermore, the local government should continue to supply such programs to bolster sustainability in the San Joaquin Valley and meet

SLCP reduction goals by 2030. The area around Stockton is a great area to invest in anaerobic digestion to ease the high concentration of methane emissions coming from an area with a high concentration of dairy farms.

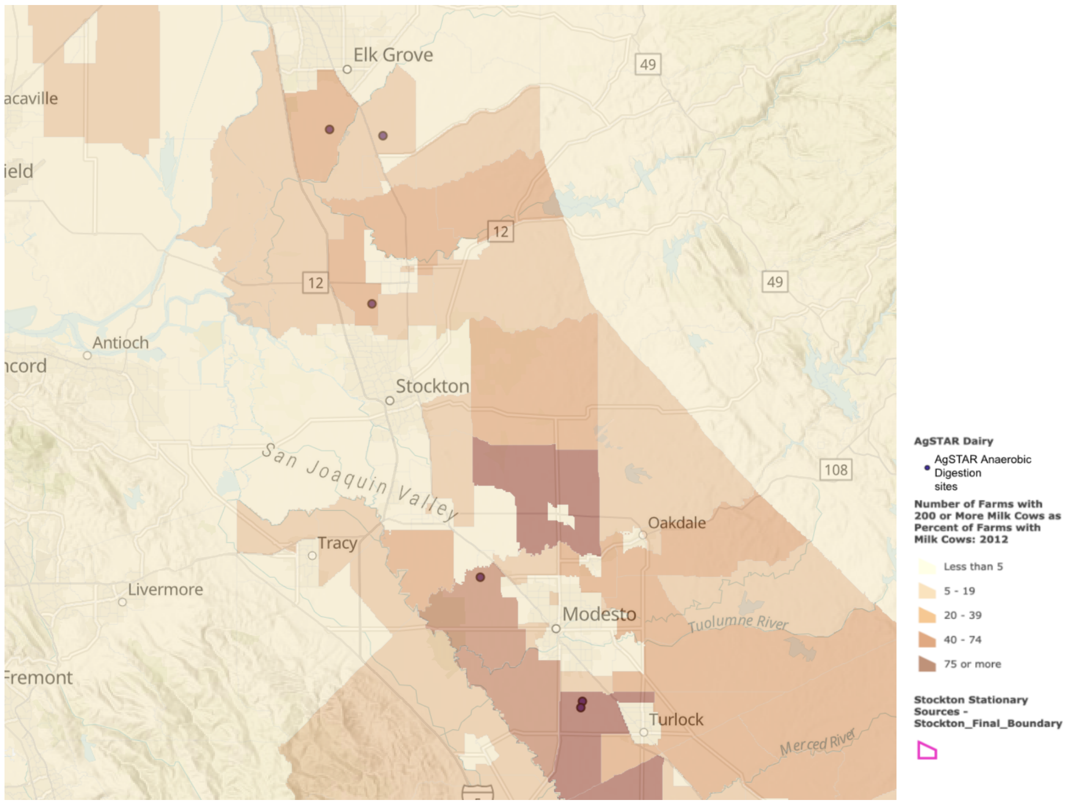

Figure 9: Map of cattle concentration and anaerobic digester sources surrounding the area of Stockton. Source: AgStar

Further research will attempt to address anaerobic digestion's efficacy in point-source methane emission reduction and address whether the current hub and spoke system approach is optimal. Furthermore, understanding the lack of anaerobic digestion technology around Stockton and the northern San Joaquin Valley will help in deliberating the best strategy to anaerobic digestion on a national level.

While anaerobic digestion is very promising, the scaling up of this technology needs to also happen in tandem with efforts to reduce enteric fermentation, which is a process digesters do not address.

The current state of enteric fermentation related methane emissions is still a topic undergoing a lot of research. Due to strong agricultural lobbies, limits on these emissions are not necessary at all and any strategies to mitigate such emissions must be funded by the government and effective in order to make any change. Yeasts, seaweeds, nitrates and even essential oils are all undergoing lab trials. For example, Asparagopsis Taxiformis, a red Hawaiian seaweed that can be grown off the coast of California looks promising for California's methane emissions, but due to its unique growing environment, it requires too unique of a habitat to survive for it to be very effective at the global scale. Trials at UC Davis are currently underway where they add a small amount to feed at the CAFOs. How it would be implemented for farms that practice open grazing is still unsure.

Design Plan for California 2027

In our sector's current state, we see problems including a lack of data and regulation as well as a food system that operates with the goal of profit rather than health and wellness. These problems present opportunities to reach a preferred system at varying time scales.

In the short term, leverage points that will help move the sector toward goals of methane reduction include incentivizing digesters and providing benefits for emissions reduction on a voluntary basis. According to the EPA, digesters become feasible for farms that have 500 or more cattle (OAR US EPA 2014). Enacting a policy to require farms of 500 or more cows to have a digester is a promising way to deal with manure that has a net negative cost, as the biogas produced by digesters is very profitable in the long run. To mitigate unintended consequences of subsidized biogas from digesters, we also recommend putting in place a limit on the number of cows a dairy farm may have, so as to limit the thus-far unchecked growth of the industry. In addition, we recommend that the government invest in collecting more robust emissions data and requiring this information to be available publicly, as the current state is very data poor.

Government investment in research to reduce enteric fermentation needs to be expanded. There are some programs already in action that research organizations can draw funds from which include the Dairy Digester Research and Development Program, the Greenhouse Gas Reduction Fund and the California State General Budget Fund; they have allocated $32 million dollars for livestock methane reduction. With these funds, research into the viability of promising feed additives such as 3NOP and red seaweed is financially possible. These feed additives are added to livestock feed to reduce methane releases from burps, and different options have seen as much as 90% reduction. These feed additives are in active research and so far have not shown to alter the quality of the product or efficacy of the animal. Barriers to fully integrating additives include availability and cost, which is why government investment can be extremely beneficial. Technology development, however, is not necessarily guaranteed, so investment in this research must happen alongside the more tangible, short-term regulations mentioned above.

All the previously mentioned solutions, however, are strategies to influence the current system. Subsidies and taxes can be considered parameter changes, which, according to Donella Meadows, are less preferable leverage points in terms of meaningful change ("Leverage Points: Places to Intervene in a System" n.d.). On a longer time scale, we can imagine a system based on greater local food sovereignty and community engagement, which is illustrated in Figure 10 below.

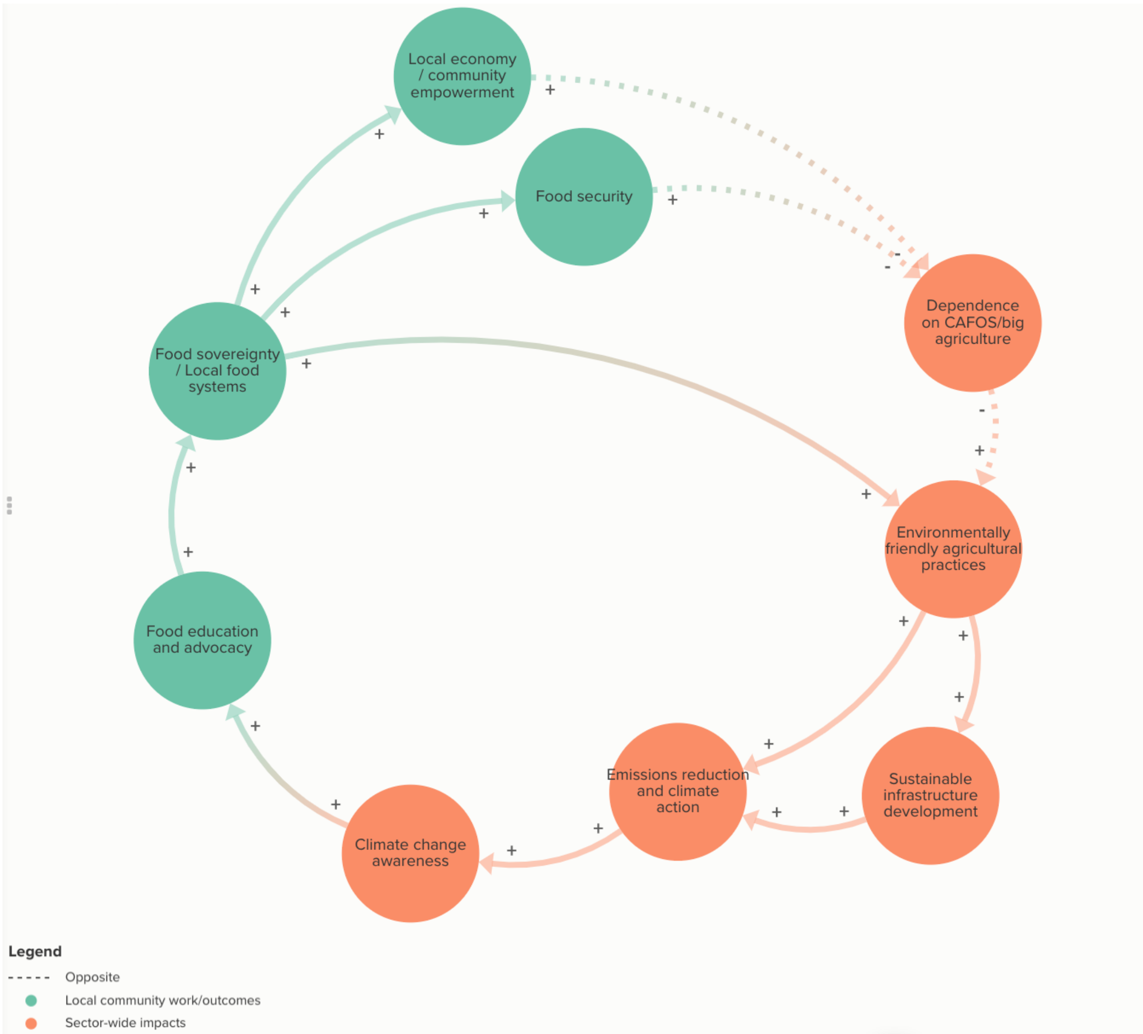

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Figure 10: Preferred food systems map

By engaging the leverage point of food education and advocacy that was identified in Figure 3 in the Problem State section, Figure 10 illustrates that a greater awareness of food justice can lead to more localized food sovereignty, a self-sustaining state of equity in which communities have just access to food, leading to less dependence on big agriculture, thus mitigating the environmental effects of industry practices. By focusing on empowering communities through both monetary and educational resource investment, on a longer time scale a system in which community needs and health are prioritized over large-scale profit can arise. Initial actions toward education can look like investing in food education in primary schooling, integrating practices such as meatless Monday campaigns into schools and other institutions, and investing community resources into infrastructure for urban agriculture. In addition to the net good of methane emissions being reduced, a more collective approach to agriculture will strengthen communities by allowing them to engage in their own food systems, thus providing both social and economic benefits.

In Figure 11 below, we can see that the implementation of anaerobic digesters holds a lot of potential in methane emission reduction, especially in the case of superemitters like CAFOs. Scaling up and investing in digesters is critical, and the only real cons (disruption to production during construction and start-up cost) are financially insignificant in the long run, as biogas is very lucrative for farmers as it generates additional revenue from environmental credits similar to the cap and trade system. While it is good that biogas is lucrative, we do want to be careful that the benefits from biogas do not encourage an expansion of the dairy industry, so an ideal policy would be to subsidize the installation of a digester and allowing credits from biogas to cover operations, but having limits to profit from biogas as well as a ceiling on how many cattle a farm can have. Using funding that is already available can be a critical way to take advantage of a leverage point in order to incite the upper half of the system map's feedback loop.

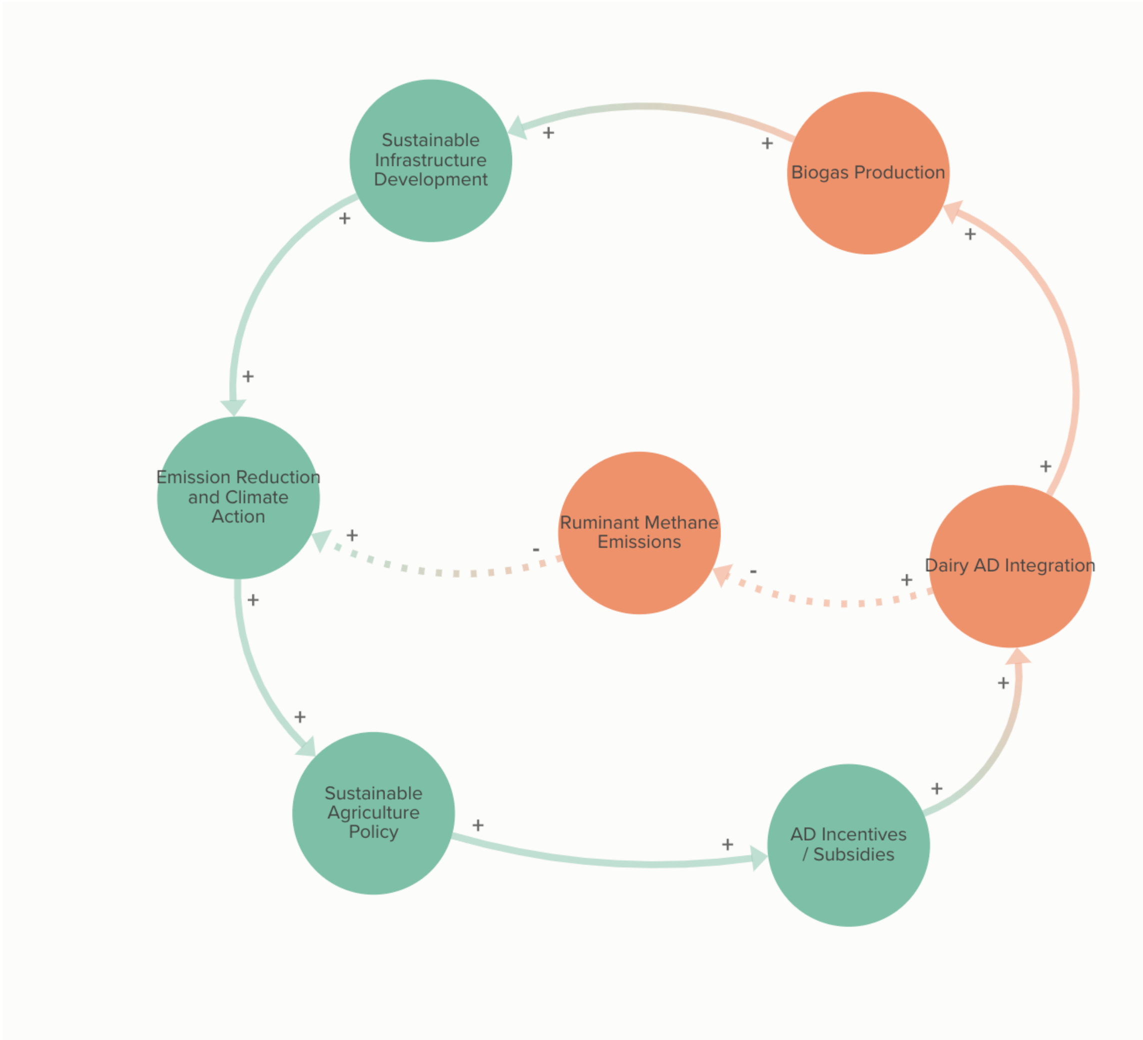

Figure 11: Systems map describing anaerobic digestion (AD) integration to ruminant livestock industry in a preferred state (same legend as above)
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Infrastructure to support biogas usage in trucks and tractors is still in active development and can be a point for farmers to generate their own fuel to power their equipment, after it runs through the refining process. This localizes the source of resources that the agricultural industry uses and therefore makes farms more self reliant.

Implementation Plan

This is a general summary of our implementation plan which spans until 2030. Immediate actions would include investing in research for mitigation technology for enteric fermentation. Since researchers are already looking into technologies such as feed additives, more funding should be allocated to this work and to the possible scaling up of technologies when they are proved viable. In 2022 and 2023, we would want to see an increase in educating the general populace about food systems and animal products. An example of how we could go about this could be by introducing Meatless Monday campaigns in public schools to get more of the general public thinking about the environmental impacts of ruminant livestock.

January 1, 2024, is the earliest CARB will be authorized to introduce regulation to meet the methane goals, and one of these regulations we recommend is to mandate that all farms with at least 500 cattle adopt an anaerobic digester system. At the same time, methane-specific data collection should be incentivized, either publicly with more robust satellite data or through vehicle-mounted methane sensors for more individualized sources. Although this cannot be enforced until 2024, immediate actions can be publicizing these coming regulations so that there is less of a lag time once the law can actually go into effect. Funding could come from California Climate Investment funds that have already funded many existing digester projects as well as the pilot financial mechanism outlined in SB 1383 that CARB has been enlisted to develop to mitigate the financial uncertainties of SB 1383 outcomes in the dairy and livestock industry (CARB).

Following the groundwork of education we believe should be enacted immediately, we hope that better education and awareness of food systems can create enough momentum for a greater government investment in more local food systems. Local governments should be encouraged by the state to set aside land and money for community food development such as urban farming, community gardens and composting, etc.

Around 2027 is when CARB can assess the efficacy of the regulations put in place in 2024 and begin to implement more aggressive strategies to heavy emitters if necessary. These more aggressive strategies could include a methane tax as well as potential laws to make livestock diets more strictly regulated.

The hope is that by 2030 we are near our goal of reducing total methane emissions by 40%.

Strategies to Share Beyond California

The applications of the preferred system within the report can be applied to other food and agricultural systems that are lacking proper methane emission management. Methane emission reduction comes with policy backed, farmer-supported, integration of methane collection integrated into agricultural business as usual. Sustainable Agriculture policy helps develop a more green food system. Furthermore, utilizing anaerobic digestion beyond California is very feasible as long as cost is addressed and there are proper, expansive, grant and incentive programs implemented.

Developing a global food system that focuses on food education, advocacy, and sustainable infrastructure is integral across all communities. Working with local representatives, governing bodies, and production on establishing food security is a global concern and important on a small scale community level. Likewise, establishing sustainable agricultural practices that produce a secure and resilient food system shows how food systems and agricultural best practices are heavily tied. With food production fully privatized, molding local food cultures into sustainable and healthy ones is an important cultural shift and encourages private food production to follow the needs of consumers.

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Appendix

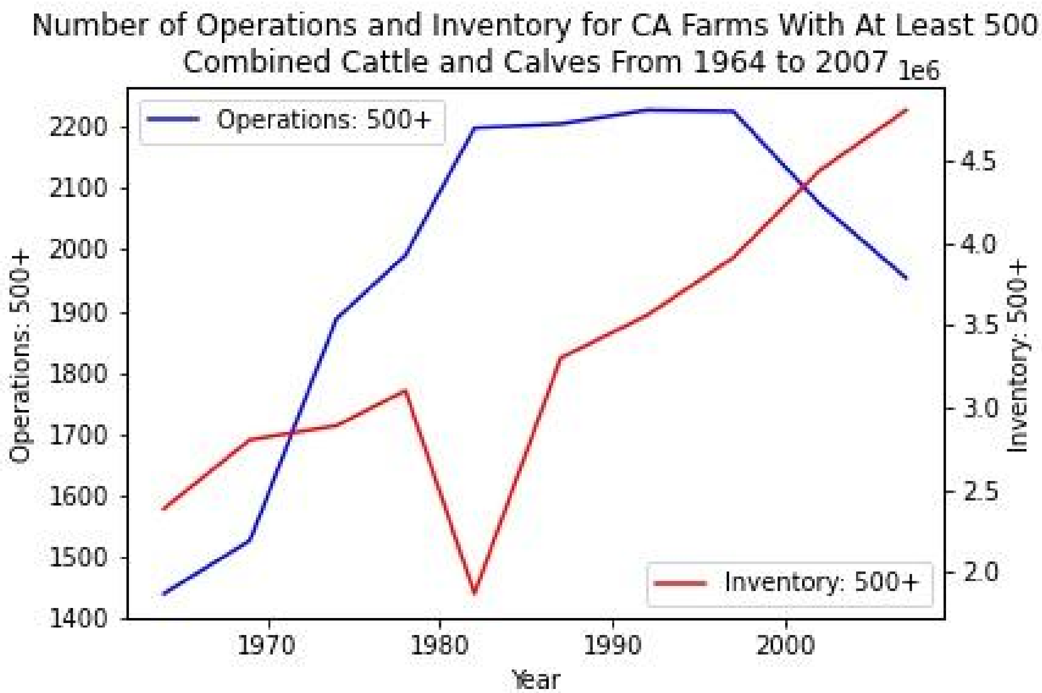

Figure A1: Graph showing the trends for farms with at least 500 cattle/calves. Notice the dip around 2000 showing the number beginning to decrease in favor of larger farms. Source: ("USDA - National Agricultural Statistics Service - Census of Agriculture" n.d.)

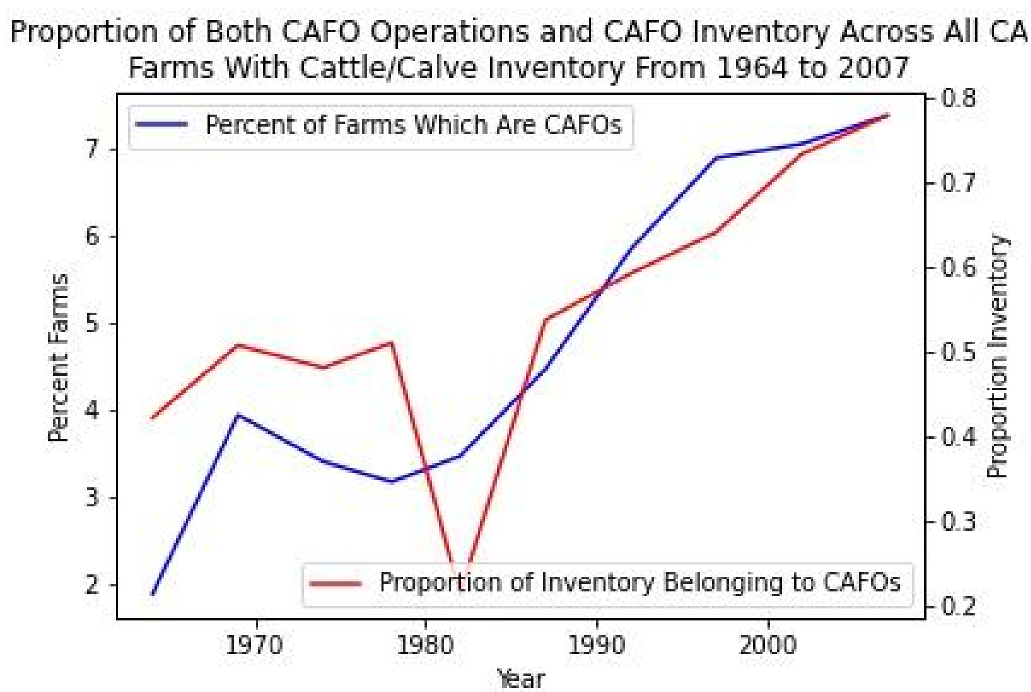

Figure A2: Graph showing the relationship between CAFOs and their inventories as a percentage of the respective totals. This means that CAFOs see an increase of 5.5% while total cattle/calves inventory rises by a whopping 35%. Source: ("USDA - National Agricultural Statistics Service - Census of Agriculture" n.d.)