RECOMMENDATIONS FOR SHORT-LIVED CLIMATE POLLUTANTS

AN AGRICULTURAL WORKGROUP REPORT FOR THE CALIFORNIA AIR RESOURCES BOARD AND CALIFORNIA DEPARTMENT OF FOOD AND AGRICULTURE

JUNE 2015

California Department of Food and Agriculture

Contents

Executive Summary

The California Department of Food and Agriculture (CDFA) assembled a group of technical experts and agricultural representatives (SLCP Workgroup) to identify strategies to reduce short lived climate pollutants (SLCP) emissions from California agriculture; particularly methane. The SLCP Workgroup acknowledged that the agricultural sector should continue to accomplish reductions of greenhouse gas (GHG) emissions, including short-lived climate pollutants, through voluntary practices and technologies. The SLCP Workgroup disagrees with the inclusion of the livestock industry in the Cap and Trade Program as suggested on page 21 of the California Air Resources Board, *Short-Lived Climate Pollutant Reduction Strategy Concept Paper*[1]. The SLCP workgroup believes that the inclusion of the livestock industry in the Cap and Trade Program would be counterproductive for several reasons: (1) there remains uncertainty in inventory methodology for methane emissions, (2) the cost of installation and maintenance of manure management technologies is prohibitive and would result in the loss of the industry and its positive impact on the California's economy to other states.

The SLCP Workgroup's key recommendations, as outlined in Section III of this report, include principles of cooperation, ambassadorship, and prudence as well as recommended actions for reducing SLCP emissions from agriculture in California. Many of the recommendations offer co-benefits that are in line with other State initiatives. The SLCP Workgroup recommended actions include:

Inventory Methodology

- **Peer-reviewed research on inventory methodology regarding GHG from the agriculture sector in California.**
- **Support for programmatic investments in cost-effective, scientifically robust technologies and approaches to quantify and verify emissions and emissions reductions from agricultural sector offset projects in order to ensure that project developers and agricultural producers will participate in these projects.**

Manure Management

- **Utilize robust investments from the Greenhouse Gas Reduction Fund (GGRF) to incentivize dairy anaerobic digesters in California to accomplish the most cost-effective swift reductions of methane from the dairy industry.**
- **Investigate the cost per metric ton of GHG reduction for the most efficient solid separation technologies for dairy manure and for conversion to dry manure management systems and develop incentive programs for these technologies.**
- **Avoid and remove any unnecessary regulatory barriers to composting of dairy manure and digestate.**
- **Examine trade-offs in methane production potential, regulatory burdens and market considerations between on-farm composting and centralized facilities. Investigate the potential to create centralized composting facilities to accept livestock manure and other agricultural feedstock such as perennial crop trimmings to reduce methane production and increase the quality of products intended as soil amendments.**

[1] CARB. 2015. Short-lived Climate Pollutant Reduction Strategy Concept Paper. Page 21.

- **Investigate the role of biochar as a soil amendment with multiple soil health impacts, including soil moisture retention, and the potential to create long-lived soil carbon pools.**

Enteric Fermentation

- **Research the use of dietary additives (e.g., grape pomace and others) to reduce methane emissions from enteric fermentation.**

Rice Cultivation

- **Adopt and recognize the Rice Cultivation Offset Protocol as an effective mechanism to encourage methane reductions in a manner that minimizes water bird and other wildlife habitat impacts.**

Black Carbon

- **Reduce black carbon emissions by encouraging forest management practices that reduce fire risk.**
- **Study the cost-effectiveness of a new pump electrification program funded by the Greenhouse Gas Reduction Fund.**

The information presented in this report, including key assertions, provides a framework for continued collaboration with stakeholders. The agricultural community anticipates engagement in policy development that sustains agriculture in California for benefit for all Californians.

I. Introduction

Senate Bill 605

Short-lived climate pollutants are GHGs with relatively short atmospheric lifetimes, a few years to decades, and have strong global warming potentials (GWP). Accomplishing swift reductions of SLCP emissions is a climate change mitigation strategy that can have a significant impact on the overall emission inventory and on cumulative climate change impacts over the long term. Policies are needed to reduce short-lived climate pollutants in order to prevent the global temperature from rising 2°C, which is a United Nations climate goal (agreed upon in 2010) (Institute for Governance and Sustainable Development, 2013).

Senate Bill (SB) 605 (Chapter 532, Statutes of 2014), requires that the State of California take additional actions to inventory and reduce short-lived climate pollutant emissions. SB 605 requires the California Air Resources Board (CARB) and other state agencies to engage industry stakeholders to identify strategies to reduce emissions of SLCPs. SB 605 also refers to the need to identify data gaps, barriers to reducing SLCPs, and asks that stakeholders determine new or alternative opportunities to reduce SLCPs and to identify the co-benefits of the reduction opportunities (Senate Bill 605, 2014).

Emissions of SLCP from California Agriculture

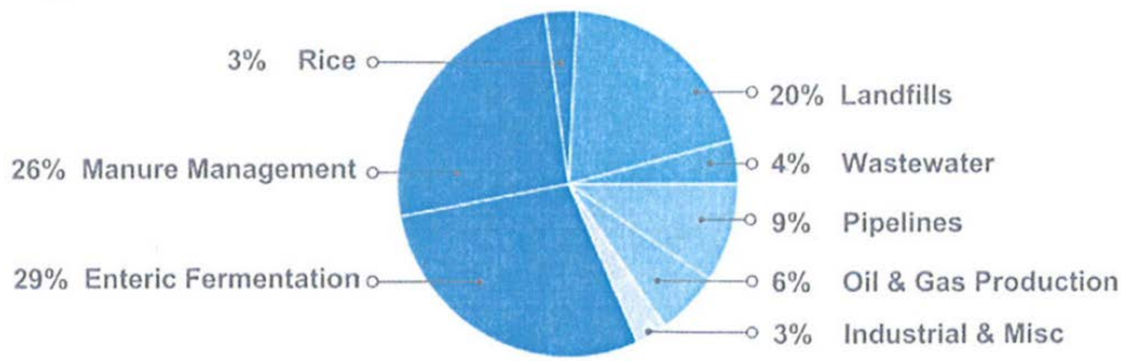
Methane

The total amount of all GHG emissions from California agriculture accounts for 8% of the GHG emissions inventory in California. Of this share, methane[2], a SLCP, makes up the largest portion (60%) of agriculture's contribution. Therefore, reducing methane emissions from California agriculture can significantly reduce the industry's overall contribution to California's GHG inventory.

According to the California Air Resources Board's greenhouse gas inventory in 2012, the main sources of methane emissions from California agriculture are (1) enteric fermentation from ruminants and (2) manure management systems (Figure 1). The scientific community is currently debating the accuracy of the CARB inventory of agricultural methane sources in California. For example, California's inventory reflects that enteric fermentation and manure management are nearly equal contributors to methane emissions but this is not consistent with other inventories where enteric fermentation has a much higher contribution. According to the United States Environmental Protection Agency (US EPA) Inventory of methane sources in 2012, enteric fermentation represented 25% of methane emission in the U.S. while manure management was only 9% (US EPA, 2014).

[2] Methane is a greenhouse gas with an atmospheric life of 12 years and a GWP 25 times that of carbon dioxide.

FIGURE 1: CALIFORNIA METHANE EMISSIONS FROM ALL SECTORS (2013)

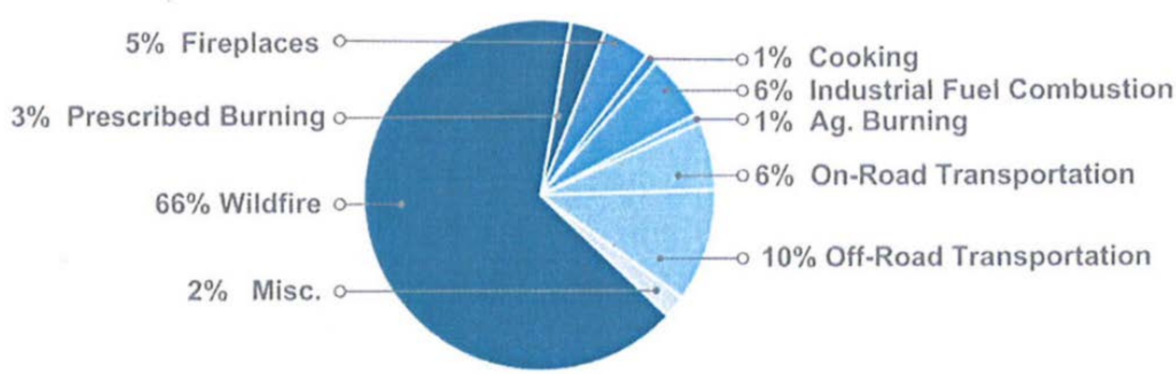


Methane emission contributions from all sectors of the California economy in 2013 (CARB, 2015).

Black Carbon

Black carbon, a term for a group of pollutants formed during incomplete combustion, is also a SLCP and is emitted from agricultural operations in California (e.g., diesel combustion, agriculture residue burning). Agriculture contributes to black carbon emissions, but is a much smaller contributor than other sectors. The largest source of black carbon emissions in California is wildfires (Figure 2). Black carbon strategies were also discussed by the SLCP Workgroup, although it was noted that the agricultural sector, along with other economic sectors, has already significantly reduced its black carbon emissions since the 1960s.

FIGURE 2: BLACK CARBON EMISSIONS FROM ALL SECTORS (2013)



Black carbon emission contributions from all sectors of the California economy in 2013 (CARB, 2015).

CDFA Short-Lived Climate Pollutant Workgroup

In order to engage the agricultural community regarding reductions of SLCPs, the California Department of Food and Agriculture (CDFA) assembled the SLCP Workgroup. The SLCP Workgroup consisted of technical experts and agricultural representatives who worked to identify strategies to reduce SLCP emissions from California agriculture; particularly methane. Regarding potential strategies, the SLCP Workgroup was asked to consider and (1) identify the barriers and challenges of implementing strategies and practices to reduce methane, (2) the environmental and/or agronomic co-benefits of the identified strategies and practices, (3) the economic benefits and (4) the research needs for reducing methane in California agriculture. The SLCP Workgroup emphasized that there were other important considerations including environmental, agronomic, or economic impacts; cross-media impacts; data trends; unintended consequences; and lessons learned. The Workgroup agreed to assess these other criteria when forming recommendations.

The SLCP Workgroup met four times in April and May, 2015 in order to compile recommendations in a report to the California Air Resources Board and the California Department of Food and Agriculture.

The initial meeting of the SLCP Workgroup on April 13, 2015 involved a discussion of the United Nation's Food and Agriculture Organization's 2013 report titled, *Animal Production and Health Paper on Mitigation of Greenhouse Gas Emissions in Livestock Production* (Hristov et al, 2013). The SLCP Workgroup assessed the lists of mitigation opportunities outlined in the report to determine the strategies that would have the highest potential and applicability in California. At the second and third SLCP Workgroup meetings, the group's discussion on these topics led to possible recommendations for further development at the final meeting.

During the SLCP Workgroup's discussions several themes emerged that warrant early assertion in this document:

Assertions

1. ***Emissions of methane from agricultural sources are due to biological processes and are difficult to quantify***. The methane generated from agricultural systems is primarily a product of methanogenic archaea microorganisms. These microbes are active in anaerobic conditions such as manure lagoons, ruminant digestive systems and flooded soils. Methanogens are an important part of the web of life and facilitate decomposition of organic matter. It is challenging to quantify methane emissions from these biological systems because multiple variables such as temperature, and biological and chemical composition of the environment influence methane production.
2. ***California agriculture contributes nutritional food products and has a key role in local and global food security***. With a global population expected to climb to 9 billion by 2050, maintaining strong food production and increasing production efficiency are critical to food security. California leads the way in agricultural efficiency gains. California's diverse agricultural products are consumed throughout the world, not just in California.
3. ***There must be flexibility in policies to accommodate changing environmental or economic conditions***. California agriculture is susceptible to changing conditions (e.g., drought, economic downturns, and fluctuating livestock populations). Policies must allow for flexibility to enable ongoing success of California's agriculture industry and to prevent movement of the industry and its economic benefits to outside of the state. Retaining the industry in the state offers the best opportunity to achieve GHG reductions, due to California's unique and pioneering responsiveness towards climate change.

4. ***Regulations on agricultural operations have dramatically increased, particularly since 2004***. The agricultural industry has responded to these regulations with compliance and in doing so has achieved multiple environmental benefits and has demonstrated feasibility and potential outcomes to other jurisdictions.
5. ***Any strategies to reduce emissions from biological sources may have unintended cross-media impacts which need careful consideration before actions are taken.***

Contributions of the Dairy Industry

According to the CARB GHG inventory, the largest agricultural sources of methane are manure management and enteric fermentation of dairy cattle. Enteric fermentation of non-dairy cattle is the third largest source of agricultural methane emissions. All other agricultural sources of methane are much smaller, such as rice cultivation and manure management of non-dairy cattle, which are fourth and fifth respectively (CARB, 2014). It is important to consider the impact of the dairy industry beyond the estimated GHG emissions. The California dairy industry provides many valuable benefits (e.g., nutritional, economic) to the state and the rest of the nation, these benefits outweigh its contribution to the California GHG inventory.

A new report from the University of California Agricultural Issues Center titled, *Contributions of the California Dairy Industry to the California Economy*, describes the important contributions that the California dairy industry makes to the economy. Dairy farms and processing provide 189,000 full-time jobs and $65 billion in wholesale value to California's gross domestic product (Sumner et al, 2015). In 2014, 20.5% of U.S. milk was produced by California's 1.7 million dairy cows, making California the number one dairy state in the nation. Forty percent of the milk that is produced and processed in California ultimately is exported out of the state as processed products such as cheese, whey and butter (CDFA, 2015), (Sumner et al, 2015). These positive contributions of the dairy industry merit significant consideration when seeking GHG reductions from the agricultural sector.

II. Potential Strategies for SLCP Reductions from California Agriculture

The following sections summarize the discussion points of the SLCP Workgroup as members considered the challenges, benefits and impacts, and important data gaps of each strategy that was identified at the first meeting of the workgroup.

Enteric Fermentation Strategies

Critical Relationship between Production Efficiency and Emission Intensity

Methanogens, microbes that produce methane through decomposition processes, live within ruminants as part of a complex microbiome. The ruminant microbiome allows them to utilize fibrous feedstock that other animals are not able to digest. The implications are significant; ruminants turn these feedstocks into valuable human nutritional products. The composition of the microbiome can influence animal productivity (milk or meat); therefore, it is important that any strategies targeted to reduce methane from enteric fermentation do not negatively influence productivity (Knapp et al, 2011). This is especially true in light of the growing local and global population and food security needs in the future.

Livestock production efficiency has an inverse relationship with the greenhouse gas footprint of the systems. Animals that produce more milk and/or meat result in fewer emissions of GHG per unit of product. This is demonstrated in Figure 3, showing the relationship in milk production and GHG footprint.

Potential strategies to reduce methane emissions from enteric fermentation identified in literature include herd genetics, microbial genetics, nutritional strategies, and improved animal health and fertility (Knapp et al, 2014). The SLCP Workgroup discussed many of these approaches, but concurred that the potential to reduce methane from enteric fermentation in California is limited, due to the fact that U.S. livestock and dairy cattle are already among the most efficient producers in the world. In 2007, U.S. dairy cows produced the same amount of milk as in 1944 using 21% of animals, 23% of feed, 35% of water and 10% of land. (Capper et al, 2009). Since 1944, the dairy industry has reduced methane

FIGURE 3: INVERSE RELATIONSHIP BETWEEN THE GHG EMISSIONS AND MILK OUTPUT PER DAIRY COW (GERBER ET AL, 2011)

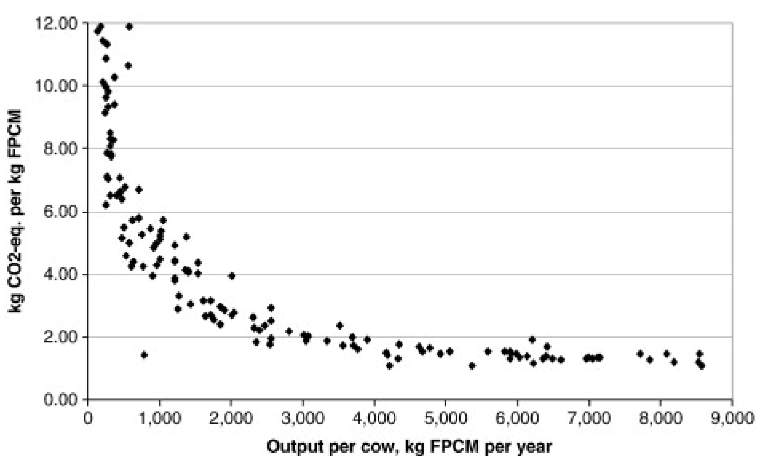


Figure 3 illustrates the importance of production efficiencies when considering GHG emissions livestock systems. Dairy cows that have higher production outputs, shown on x-axis as kg of fat and protein corrected milk (FCPM), are associated with a smaller emission intensity, which is shown on the y-axis as kg CO_2e per kg of FCPM.

emissions by 43% per billion kilograms of milk (Capper et al, 2009). In the past 20 years, the milk produced per cow in California has increased by 50% (Sumner et al, 2015).

The U.S. beef industry has made similar gains in efficiencies. In 2007 four beef cattle produced the same amount of beef as five beef cattle in 1977 (Capper, 2010). These huge gains have occurred because livestock producers continue to invest in the most efficient animals, feeds, and technologies without GHG mitigation as a motivating factor. It is likely that increases in efficiency will continue with the same economic motivation. Consumer and/or trade partner apprehensions can limit the technologies that can be used to improve animal productivity. For example, hormone use could reduce the lifespan of beef cattle before harvest but is often negatively viewed by the consumer. Producers must be cautious about feed additives or other new technologies as there can be unintended impacts (e.g., monensin in groundwater; Watanabe et al, 2008).

In 2014 each California dairy cow produced on average 23,700 pounds of milk (Sumner et al, 2015; USDA NASS, 2015). In contrast, in the developing world production per cow can be lower than 1,000 pounds of milk per year (FAO, 2015; IPCC, 1996). The SLCP Workgroup discussed the need for improved production efficiency in the *global* livestock sector. This is critical for future food security and income equality. Increased focus on global livestock production efficiency will reduce the greenhouse gas footprint of food systems, not to mention reduce waste and conserve critical resources such as water and land. The SLCP Workgroup noted that the improvements in the carbon footprint of California's livestock industries are not captured in the Air Resources Board GHG inventory (which does not account for efficiency).

The SLCP Workgroup noted that gains in various aspects of production efficiency for dairy and beef cattle (e.g., genetics, nutritional, health) have been significant, but that reproductive efficiency has not experienced the same improvements. The number of months that a dairy cow lactates has decreased in the last decade from an average of 31 months to an average of 25 months (UC CSU Environmental Mitigation Panel, n.d.). Research to analyze production efficiency and profitability to improve longevity in the cattle herd could be valuable, but the Workgroup also conveyed that market considerations come into play. Hence, improving reproductive efficiency in cattle may not ultimately lead to reduced methane emissions.

Research on Dietary Supplements

The Workgroup recognized that although the potential to reduce emissions from enteric fermentation is quite limited, research on dietary supplements (e.g., grape pomace) shows some promise for small reductions. The Workgroup suggested further research to identify potential feed additives or ingredients that have methane reduction potential without impairing intake, milk production, milk composition and body weight gain.

Manure Management Strategies

Manure management practices on California dairies are tailored to the specific conditions and restraints of each dairy operation. California dairies operate under strict environmental regulations that require management of nitrogen, salts, volatile organic compounds, particulate matter and odor. Additional proposed Federal rules will increase regulatory scrutiny on manure management or downstream use. Animal housing design dictates, to a large extent, current methods of manure collection and management. Liquid storage structures are utilized on most facilities to store washwater from milking parlors and some amount of manure collected from milking operations. Dry and open lot housing has manure collected in a solid form (water has evaporated to some extent). Manure from freestall lanes or outdoor concrete feed lanes can be scraped (handled as slurry or dry) or flushed (handled wet). Freestall facilities typically have dry lots associated with the housing areas; some manure will be deposited and handled as a dry solid.

The SLCP Workgroup discussed several opportunities to reduce methane emissions from manure management. Any of these strategies could potentially mitigate methane on a California dairy, but none are a one-size-fits-all solution. Dairies must have flexibility to implement systems that work for their business economics, herd size, and crop nutrient needs, and allow for compliance with multiple air and water quality protection criteria. Additionally, any change made in manure management on a dairy will result in cross-media consequences (e.g., air quality, nutrient management, labor, energy inputs). These impacts require careful deliberation by the dairy operator before implementation of a new manure management practice. A thorough analysis of multimedia impacts should be done on individual operations before mitigation measures are implemented. It is important that fate and form of nitrogen (organic versus ammonium), total salt available for loading to soil, and impacts to other known environmental constituents of concern be evaluated and predicted. Accordingly, efforts to promote methane-reducing management practices should reflect the differences across contexts and the need for flexibility.

Critically, no field measurements of methane emissions from manure management systems have been made in California and research is needed to improve confidence of methane emission calculations in order to better quantify the potential benefits of emission mitigation practices. A comparison of global field measurements from dairy manure management components and emission modelling showed that there is significant discrepancies between field measurements and models (Owen 2015).

Anaerobic Digesters

Anaerobic digesters offer the greatest quantifiable potential for methane reductions from manure management in California, particularly on large dairies. Anaerobic digester technology is considered a GHG mitigation opportunity that is ready for implementation and has high potential for emissions reductions (Olander et al, 2011). U.S. EPA estimated that California has nearly 900 dairies with potential[3] for anaerobic digestion which would result in 341,000 MT of methane reduction and energy production of 25.7 million MMBtu/year (US EPA, 2011). During the SLCP Workgroup meetings, it was suggested that the installation of 100 to 200 digesters in California could result in reductions of 2.0-2.5 MMT of CO_2 equivalent per year, 60-70 MMT over the lifetime of the digesters (based on the digesters servicing 500,000 cows).

Digesters offer a multitude of co-benefits that can contribute to California's environmental goals. The biogas generated in digesters is a flexible low-carbon energy source which can be utilized for electricity generation, injected into natural gas pipelines, or used as a transportation fuel. This flexibility is in line with Governor Brown's renewable energy and transportation goals[4]. Additionally, the solid digestate,

[3] These were defined as dairies with herd >500 head and liquid manure management systems.
[4] Governor Brown's Inaugural Address on January 5, 2015 included 2030 goals of increasing renewable energy generation years by 50% and reducing reliance on petroleum for transportation by 50%. http://gov.ca.gov/news.php?id=18828

the remaining solid by-product of digestion, can be utilized as a soil amendment to increase soil organic matter as part of California's Healthy Soil Initiative. Other co-benefits of anaerobic digesters include reduced odor and emissions of volatile organic compounds (VOCs), ammonia, and hydrogen sulfide. Economic benefits include additional revenue for the dairy farmer and employment opportunities associated with construction, operation and maintenance and by-product processing and sales.

There are potential negative environmental impacts that can result from the installation of digesters. The use of digester biogas for electricity generation using internal combustion emits oxides of nitrogen and sulfur (NOx and SOx). There are best available technologies that reduce emissions of NOx and SOx, but technology is expensive and does not totally eliminate emissions. This air quality trade-off perhaps hints at the preferable use of biogas for transportation fuels or for pipeline injection instead of on-site electricity generation. Technologies that do not involve internal combustion, such as fuel cells and micro turbines, while currently not economically feasible, may warrant further research and development given their potential to generate electricity with low or no NOx emissions.

Anaerobic digesters do not resolve the water quality concerns posed by manure as digestate still needs to be properly handled and land applied. The digestate may have a more consistent nitrogen mineralization response and combined with nutrient management plans can help mitigate risks to groundwater and air quality (i.e., nitrous oxide emission), however, few studies exist making this a priority research area. Despite this, some water quality benefits can be expected from the installation of new anaerobic digesters. For example, new lagoon digesters are typically double-lined to protect against seepage to groundwater.

There are several barriers to anaerobic digesters being widely installed on California's dairies. Clearly, the capital investment of building the digester is large (millions of dollars and dependent on herd size). Digesters also require maintenance which translates into additional costs. Other costs are also prohibitive and variable. For example, the interconnection to the electric utility or natural gas pipeline is expensive and ranges from $100,000 to $1,000,000 for an electric interconnection (California Dairy Campaign, 2013). Dairies need to be able to obtain a favorable power purchase agreement with a utility to ensure that installing and maintaining an anaerobic digester is cost-effective and good business-sense in the long term. Senate Bill 1122 moves in the right direction, requiring utility companies to contract with renewable bioenergy producers including dairies. In the case of pipeline injection of renewable natural gas, additional policies may be required in order to encourage natural gas companies to contract with dairy biogas producers. And finally, the fleet of vehicles and farm equipment that operates on compressed renewable natural gas is limited. If that portion of the transportation sector grows, there will be increased demand for dairy biogas utilized as a transportation fuel.

The SLCP Workgroup therefore, concluded that the highest potential strategy to reduce methane emissions manure management is the voluntary installation of anaerobic dairy digesters on dairies where the economic pay-off and the nutrient value of the digestate are certain, while acknowledging the significant challenges posed by digesters' high costs. CARB should ensure that the Compliance Offset Protocol Livestock Projects continue to be available as an offset mechanism to help with the voluntary deployment of methane digesters across California and to enhance the economics of installing and operating these systems. Other manure management strategies (discussed below) do not offer the same quantifiable emissions reduction certainty at this time or potential for renewable energy generation.

There is a critical need for further research to quantify the comparative benefits of these other practices.

Solid Separation

The SLCP Workgroup discussed solid separation as another potential strategy to reduce methane emissions from manure wastewater lagoons. Solid separation is the process of removing a portion of the solid manure (organic matter) from the liquid waste; this reduces the amount of substrate for methanogens resulting in reduced methane emissions. Many dairies (63 – 70%) already employ solid separation (Meyer et al, 2011) to conserve space in the lagoon or to improve nutrient management capabilities on cropland. The solid separation systems commonly used on California dairies currently are not as effective at removing solids (e.g., settling basins and single screen mechanical separators) as other technologies that are not as common such as weeping walls and double-screened mechanical separations.

Many dairies utilize some level of solid separation for the agronomic and environmental co-benefits. Separation reduces odor, reduces lagoon maintenance, produces animal bedding and facilitates nutrient management. The SLCP Workgroup indicated that there may be potential to increase the number of dairies using separation technologies and there is also potential to improve the efficiency of separation. Weeping walls, which are not commonly used management practice on California dairies, can be 49-80% effective at removing solid sources of volatile compounds (Meyer et al, 2004; Mukhtar et al, 2011). If weeping walls were incorporated on dairies in California at 60% efficiency, they could reduce the amount of manure volatile solids entering lagoons significantly and therefore, would also be expected to reduce methane emissions from lagoons significantly. Research could demonstrate the technological and economic feasibility of such practices. Similarly, double-screened mechanical separators are not common on California dairies, but can achieve up to 65% efficiency at removing volatile solids from liquid manure effluent (Chastain, 2008). As such, this might also be a valuable tool to reduce emissions from lagoons however, research is needed to demonstrate the technological and economic feasibility of this method. This could be accomplished fairly rapidly as these technologies already exist and are in use on some dairies – although for other purposes than methane reduction.

A barrier to installing separating technology is the cost to the dairy operator. Additionally, there are logistical and operational considerations for dairies when deciding to use a specific type of separator. Weeping walls take up considerable land space. Mechanical screen separators require electricity and fresh water to operate. Dairies have to weigh the needs and limitations of their individual operations (e.g., land restraints, nutrient loads, need for bedding, labor, water availability, etc.). Therefore, a better understanding of the circumstances that support utilizing these technologies could be helpful in designing incentive programs

Economic incentives to promote the increased use and efficiency of weeping walls and double-screened mechanical separators could achieve more widespread adoption on California dairies along with the associated methane reduction benefits of these practices.

Conversion to Dry Manure Management Systems

Scraping or vacuum removal of manure from animal housing areas is another practice that can prevent methane emissions because manure is stored in comparatively aerobic conditions. The manure can be composted or stockpiled. Many dairies in California utilize dry manure management; sometimes being primarily dry, but often in tandem with some liquid manure management (Meyer et al, 2011; Krich et al, 2005). The use of scrape systems does not completely remove the need to use water to clean milk parlors or wash down cattle. The amount of manure stored in water and, therefore in anaerobic conditions, is significantly less and methane emissions can be dramatically reduced – perhaps by more than 90 percent – when dry systems are used (Owen and Silver, 2015).

The SLCP Workgroup discussed the reasons why many dairies in California selected to install flush manure removal systems. The reasons for using flush systems included the low energy use of the system, reduced labor, reduced risk of injuries to workers and animals and improved animal health.

The benefits of using a dry manure management system include the reduced need for lagoon capacity. Similarly, if a dairy has limited available cropland to accept lagoon water, reduction of the amount of liquid manure can be beneficial to their nutrient management planning. Land application of dry or composted manure adds important plant nutrients (though as a slow-release fertilizer) while also increasing soil organic matter. Increased soil organic matter improves water and nutrient retention and can decrease erosion by improving soil structure. Dry manure or compost is also more economical to transport off of the dairy than liquid manure, an important consideration for dairies with excess nutrients for the available land.

There are potential negative considerations of dry manure systems. Emissions of some air pollutants are increased including odors, ammonia, VOCs and hydrogen sulfides. There are increased labor costs associated with dry systems. Storage systems and facility maintenance can be more costly than flush systems. In particular, concrete flooring needs to be replaced more often due to the physical scraping of the floor. Also, scraping or vacuum systems result in increased fossil fuel or electricity use and require maintenance (additional cost).

Dry manure systems can, in some instances, reduce the ability of the dairy farm to utilize the manure nutrients because manure in its dry form does not offer the same flexibility (application timing). There may be a reduction in plant available nitrogen depending on storage and application practices. Optimal management would produce similar plant available nitrogen among liquid and solid manures, but this is primarily a function of how fast the solid manure can be incorporated into soil. The faster the incorporation, the increased availability of nitrogen to the plants. This presents complexity and additional considerations for the dairy farmer during the decision-making process. Use of a dry manure management system is quite dependent on an individual dairy's specific situation. If a dairy has limited land or lagoon storage, dry scrape or vacuum systems may be appropriate options. However, dry scrape of vacuum systems must be completed in conjunction with a plan to manage the resulting manure effectively. For instance, this may require exporting more dry manure from the dairy and even increasing use of synthetic fertilizers.

When considering dry manure management systems as a strategy for methane emission reductions, the SLCP Workgroup identified the need for research on the cost-benefit of dry technologies and implementation for each metric ton of GHG savings. Additionally, there is a need to identify cost effective air pollutant mitigation technologies and strategies in order to protect air quality from the increased emissions from dry stockpiles and ensure that air quality regulations are not prohibitive of dry systems in general.

Composting

Solid separation and conversion to dry manure management result in larger volumes of manure being stored as dry by-product, which presents an opportunity for composting. Digestate from anaerobic digesters is also an organic source for composting. The SLCP Workgroup recognized the potential for compost production from dry systems. The sale of the compost to consumers by the dairy operator could balance the increased operational costs associated with the dry technologies, solid separation or anaerobic digestion.

Research suggests that converting from slurry or stockpile manure storage methods to composted manure systems could achieve significant reductions in methane and nitrous oxide emissions. (Pattey et al, 2005). Composted manure has multiple agronomic benefits including nutrients for plants, improving water penetration in soil, sequestering carbon and promoting healthy soils which have improved water-holding capacity. Composted manure is odor free, mostly weed free and has a higher value than green-waste. The carbon sequestration benefits of the application of compost to rangelands has been shown to have significant potential in California (DeLonge et al, 2013) and has recently been incorporated into a methodology for carbon accounting by the American Carbon Registry. The proper composting of manure also eliminates human pathogens and can greatly reduce the risk of pathogen contamination of the environment when applied on agricultural lands. This would have a significant food safety benefit for growers whose farms are close to dairy operations.

Composting does have some air quality impacts, primarily emissions of ammonia, VOCs and particulate matter, but no field measurements have yet been completed in California. There are still some emissions of methane associated with composting and more research is needed to understand the magnitude of methane emissions from composting. Additionally, there are energy and labor inputs required. There are regulatory barriers for dairies that want to participate in composting. New regulations on composting facilities are pending at the State Water Resource Control Board (SWRCB). However, legislation to facilitate the increased use of compost, AB 1045 (Irwin), seeks to reduce landfill waste and streamline permitting processes for composting facilities (Assembly Bill 1045, 2015).

The SLCP Workgroup discussed the low profit margin for farms to initiate compost production. It is critical that the market for compost be sufficient to support an increase in supply. The SLCP Workgroup discussed the need for more research on co-composting of manure and digestate with perennial clippings and addition of biochar to maximize the benefits of the compost. Biochar and compost mixes have been shown to provide multiple soil health benefits (International Biochar Initiative, 2015). Biochar needs further research as a soil amendment or compost addition in order to better understand appropriate application rates for specific crops and soil types (International Biochar Initiative, 2015).

Rice Cultivation Strategies

Rice cultivation, an agricultural methane source, accounts for less than 3% of California's methane emissions and a small fraction of one percent of statewide CO_2 equivalent GHG emissions. Rice farming requires continuous flooding during the growing season. This flooding causes anaerobic conditions to occur and consequently, methanogenic activity. The California Rice Commission, Environmental Defense Fund, and the California Air Resources Board and multiple partners and stakeholders have developed a Rice Cultivation Offset Protocol that outlines farm management practices that can reduce methane emissions from rice cultivation in California and the mid-South region of the U.S.

In California, two voluntary management practices are eligible to develop offset credits through the protocol: (1) replacing wet seeding practice with dry seeding and (2) early drainage of the field before harvest of the rice crop. Dry seeding delays the onset of anaerobic conditions and therefore results in modest reductions in methane production. The credits earned by the farmers who choose to employ these practices are intended to compensate for the additional cost of the management practice and/or the increased risk posed to the crop yield or quality due to the management practice. The offset protocol was just adopted by the California Air Resources Board in June 2015 (CARB, 2014).

The development of the Rice Cultivation Offset Protocol has offered positive lessons and the development of technical tools and strategies for quantifying GHG emissions from biological systems. The partnership of the California Rice Commission and Environmental Defense Fund can serve as a model for future collaborations between agricultural and environmental organizations. Additionally the Air Resources Board recognized the significant benefit to wildlife provided by winter-flooded rice fields in California and therefore, did not pursue a practice that would have encouraged field drainage during the winter migratory water bird season.

In general, GHG emissions are difficult to measure and quantify from biological systems. During the development of the Rice Cultivation Protocol improvements were made to the Denitrification-Decomposition (DNDC) model, a model for predicting soil dynamics including GHG emissions. The improvements to the DNDC model allow for methane reductions due to management practices to be modeled as opposed to reliance on direct measurements in the field on an ongoing basis. This is an important contribution toward cost-effectively quantifying GHG emissions from agricultural non-point sources. The SLCP Workgroup recognized this and would encourage similar quantification methodology be established for other potential offset protocols.

Black Carbon Strategies

As outlined in CARB's SLCP Reduction Strategy Concept Paper, California has achieved ninety percent reductions in black carbon emissions since the 1960s, due to regulations on combustion engines and other sources such as agricultural burning (CARB, 2015). This achievement is shared across California's sectors and has provided remarkable improvements in air quality and has protected human health. The agriculture sector has contributed significantly to these reductions through multiple programs including the statewide requirements for stationary and portable diesel engines, the San Joaquin Valley Conservation Management Practice Plans for cropland and animal feeding operations, the truck rule, and the tractor rule (which is under development).

Pump Electrification

The Ag-ICE program, funded through the California Public Utilities Commission, was successful in helping many farmers convert fossil fuel pumps to electric pumps and was able to achieve significant reductions in black carbon and criteria pollutant emissions. Unfortunately, the program is no longer accepting new participants. Additionally, the provision that stabilized electricity rates for participants is ending in 2016 and electric rates are likely to increase significantly, although diesel rates are also higher.

According to information by the Agricultural Energy Consumers Association presented at a SLCP Workgroup meeting, there are still over 2,000 diesel pumps on California farms. Many of these pumps were not converted under the Ag-ICE program due to the cost of the connection to the electricity grid, the distance to the connection or the cheaper price of the diesel engines (which is no longer the case). The conversion of these pumps to electricity could result in a reduction of 500,000 MT CO_2 per year and 215,000 MT of black carbon per year and would cost approximately $10/metric ton.

The SLCP Workgroup considered the implementation of a new incentive program for pump conversions as a SLCP reduction strategy. It was noted that electricity rate increases, especially during peak hours, could be prohibitive. Collaboration with utility companies would be key to making a program successful, addressing both rates and ensuring fair accounting of GHG credits. Flexibility and safely nets for farmers would be needed. For example, in the case where specific hours of operation are required by the utility there would need to be consideration for outside factors, such as drought, that could not be helped and might influence the farmer's ability to meet or exceed pumping hours. Farmers would need assistance with line extensions and connection to the electricity grid which can cost approximately $100,000 or more per mile.

Forest Management

Due to climate change impacts such as increased temperatures, drought and pest pressures, wildfires are becoming more severe. Figure 2 shows that wildfires were clearly the largest contributor (66%) to black carbon emissions in California in 2013. The SLCP Workgroup noted that any new reductions in black carbon emissions from the agricultural sector could easily be offset by a wildfire in any given year. For this reason, improvement of forest management should be considered for black carbon reductions. Improved forest management offers many co-benefits such as increased water availability, renewable energy generation, and access of forestland for grazing.

Grazing of forest land by cattle and other livestock is an integral part in improving forest management in California. The SLCP Workgroup discussed the need for research to quantify the beneficial impacts of agricultural grazing of forests and to identify ways to streamline permitting for agricultural use in forests.

Reducing Emissions Elsewhere

The SLCP Workgroup acknowledged that California has been an international leader in reducing GHG emissions and reducing the threats posed by climate change. Additionally, the SLCP Workgroup commended the efforts of CARB to serve as an ambassador to other jurisdictions regarding policies and technologies that reduce GHG emissions. The Workgroup encouraged furthering these efforts. California contributed 0.36 billion MT of CO_2 emissions in 2012 out of a total of 39.7 billion tons of global CO_2 emissions (U.S. EPA, 2014; Garside, 2013). With less than 1% (and falling) of global emissions coming from California, GHG reductions in California should not be the only emission reductions. Other states and countries must join the effort in reducing GHG emissions.

The State should focus on promoting technology transfer and continued robust outreach efforts to boost California's agriculture industry as a model for other states and countries. The State should also design its SCLP reduction efforts keeping in mind that retaining the industry in California offers the best opportunity to incentivize greenhouse gas emission reductions. Issues of leakage should be adequately weighed and considered. California is in a position to demonstrate effective actions to others, and to do so state policies (environmental or other) must include protections for businesses and consumers at home, which then draw in other jurisdictions. The policies must be scalable so that they can serve as templates that others can adopt. Above all, the policies must ensure that agriculture is able to adapt to the economic changes and pressures that can result from California's pioneering regulatory responsiveness toward climate change. There is a need to have a clear goal that inspires global action and cooperation, and engage in the evaluation and adjustment of those policies depending on whether others are implementing similar policies.

III. Recommendations of the SLCP Workgroup

The agricultural sector should continue to accomplish reductions of GHG emissions, including short-lived climate pollutants, through ***voluntary*** practices and technologies. The SLCP workgroup believes that the inclusion of the livestock industry in the Cap and Trade Program would be counterproductive for several reasons: (1) there remains uncertainty in inventory methodology for methane emissions, (2) the cost of installation and maintenance of digester and other manure management technologies is prohibitive and would result in the loss of the industry and its positive impact on the California's economy to other states. This would not result in decreased GHG emissions from the industry as those emissions would simply leave California. California would lose the opportunity to meaningfully reduce emissions from the livestock sector in a way that helps to achieve climate and energy goals and fosters economic prosperity.

The State of California must continue to work with subnational (e.g., states and provinces), national and international partners to reduce short-lived climate pollutants and limit global temperature increases to no more than 2° Celsius by 2050. California's goal is not just to reduce emissions, but to create a model for others. Thus, in addition to pursuing research and incentives to spur reductions in California agriculture, the state should strongly advocate and support action by others outside California through communication, outreach and education.

For any of the recommended actions, there must be careful consideration of the impacts to long term agricultural sustainability and food security in California (e.g., food production, environmental quality, natural resource protection, worker safety, economic viability, and animal health and welfare and consumer preferences).

Recommended Actions

Inventory Methodology

- More research and peer review is necessary on the inventory methodology regarding GHG from the agriculture sector in California. Field measurements of emissions from manure management and the impact of mitigation practices are particularly needed along with substantiation of *current* manure management practices and the amounts of volatile solids that end up in anaerobic lagoons. Additionally, several experts have reported skepticism about the inventories of dairy enteric methane emissions compared to those from manure management.

  Due to these current knowledge gaps, the SLCP Workgroup discourages the use of labeling programs that brand companies in regard to GHG emissions.

  CalEPA and CARB should consult with industry when inventory methodologies or inputs change. The agricultural sector should receive acknowledgement and credit in the GHG inventory for voluntary emissions reductions *and* improvements in efficiencies. The inventory must reflect and be responsive to the change in management that agriculture makes; this is especially critical in the situation of biological processes such as anaerobic methanogenesis.

- CARB should continue to support programmatic investments in cost-effective, scientifically robust technologies and approaches to quantify and verify emissions and emissions reductions from agricultural sector offset projects in order to ensure that project developers and agricultural producers will participate in these projects. Less expensive aggregation and verification approaches are needed to make offset projects cost-effective for project developers and agricultural producers. There is a need for continued investments in validated, calibrated models to measure and monitor California's GHG inventory, including baselines for the agricultural sector, and changes in GHG emissions based on changes in agricultural practices.

Manure Management

- California should utilize robust investments from the Greenhouse Gas Reduction Fund (GGRF) to incentivize dairy anaerobic digesters in California to accomplish the most cost-effective swift reductions of methane from the dairy industry. Also, CARB should ensure that the Compliance Offset Protocol Livestock Projects continue to be available as an offset mechanism.

  The SLCP Workgroup discussed a specific 2-phase investment plan put forth by several dairy and agricultural organizations for utilization of GGRF funds for dairy anaerobic digesters. Phase 1 includes a $30 million investment in multiple facets of a digester hub in Kern County. A cluster of large dairies in Kern County is ideally situated for interconnection to a natural gas pipeline, building of a renewable compressed natural gas (RCNG) fueling station which could be utilized by the 150 milk trucks per day that operate in the area, and there is an opportunity to develop a digestate treatment facility to produce soil amendments.

  The second phase of the plan results in $500 million invested over five years toward building anaerobic digesters throughout the state. The grant program should streamline permitting and provide certainty in funding for digester projects (similar to the Federal 1603 program, "Payments for Specified Energy Property in Lieu of Tax Credits," where digesters received payment upon becoming operational).

  The need for a robust investment in anaerobic digesters was agreed upon by the members of the workgroup, but it was also agreed that this recommendation should not overshadow the importance of other manure management strategies (next recommendation). On many dairies, other technologies may be the more appropriate emission mitigation strategy and the potential to reduce methane emissions from those strategies is significant.

- Anaerobic digestion is not an appropriate solution for all dairy manure emissions and so research on other manure management technologies is critical for the long-term reductions of methane. Funding is needed to investigate the cost per metric ton of GHG reduction for the most efficient solid separation technologies for dairy manure and for conversion to dry manure management systems. Also, the quantification methodology needs more development for dry systems and solid separation. If the results of economic studies are promising, utilize GGRF funds to incentivize technologies such as double screen mechanical separators, weeping walls, and vacuum or scrape systems. If development of offsets are also considered, validation of the offsets must be affordable for the dairy to encourage participation.

- Research and development on best economical and agronomic uses of dairy digestate is needed to better quantify and predict plant available nitrogen and to develop guidelines and markets for digestate products. There is a need to develop organic standards for the use of digestate.

- Avoid and remove any unnecessary regulatory barriers to composting of dairy manure and digestate. Identify circumstances that minimize negative trade-offs.

- Examine trade-offs in methane production potential, regulatory burdens and market considerations between on-farm composting and centralized facilities. Investigate the potential to create centralized composting facilities to accept livestock manure and other agricultural feedstock such as perennial crop trimmings to reduce methane production and increase the quality of products intended as soil amendments. Co-composting these materials could help to facilitate multiple goals of the Healthy Soil Initiative and resolve any feedstock shortages.

- Investigate the role of biochar as a soil amendment with multiple soil health impacts, including soil moisture retention, and the potential to create long-lived soil carbon pools. Biochar production from organic and biomass wastes offers value streams and reduced economic impacts of these wastes and potential co-production of renewable energy. Biochar for use as a soil amendment should be properly characterized (physical and chemical properties) and analyzed and matched to soil and cropping systems in order to address soil and crop constraints and GHG emissions reductions.

Enteric Fermentation

- Research the use of dietary additives (e.g., grape pomace and others) to reduce methane emissions from enteric fermentation. Specifically, there is a need to study lipid and tannin concentrations to decrease emissions without negatively impacting animal health or productivity.

Rice Cultivation

- The CARB should recognize the Rice Cultivation Offset Protocol as an effective mechanism to encourage methane reductions in a manner that minimizes water bird and other wildlife habitat impacts.

Black Carbon

- California should reduce black carbon emissions from wildfires by encouraging forest management practices that reduce fire risk. Improved forest management has the highest potential to achieve significant reductions in black carbon emissions and offers co-benefits including additional water resources for beneficial uses (including agriculture), protection of wildlife and ecosystems, generation of renewable energy and increased agricultural opportunities. Permitting processes in forest use should be streamlined to include multi-media considerations with the goal to conserve natural resources. Additionally, research on the impacts of land use changes in forest settings, such as reduced grazing, in relation to increased fire risk and black carbon emissions can help guide forest management decisions.

- Study the cost-effectiveness of a new pump electrification program funded by the Greenhouse Gas Reduction Fund. Many co-benefits would result from such a program including reductions of criteria pollutants.

IV. Acknowledgements

Participants

The following is the list of industry representatives and technical experts (listed alphabetically) that participated in the SLCP Workgroup and/or provided review of the draft recommendations

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CDFA would like to specially thank Michael Boccadoro, Paul Buttner, J.P. Cativiela, Cynthia Cory, Dr. Kebreab, Dr. Mitloehner, Justin Oldfield, Paul Sousa and Stacey Sullivan for their presentations and for leading discussions of the Workgroup.

Thank you to the Center for Collaborative Policy and Grace Person (MSc) for facilitating the SLCP Workgroup discussions and providing guidance during this process. This report was drafted by Carolyn Cook (MSc), Senior Environmental Scientist at CDFA.

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