DAIRY AIR RESEARCH PROSPECTUS

A document from the Dairy and Livestock Subgroup #3.
Comprehensive outline of California dairy air research concepts and needs to effectively achieve SB 1383 goals.

The statements and conclusions reported in this document are not necessarily those of the individual members of the Dairy and Livestock Working Group. The mention of commercial products, their sources, and/or their affiliations does not constitute any endorsement. The report is available from the Dairy and Livestock Working Group website hosted by the California Air Resources Board at https://www.arb.ca.gov/cc/dairy/dairy.htm. Any questions regarding this document should be submitted to CARB at SLCP@arb.ca.gov.

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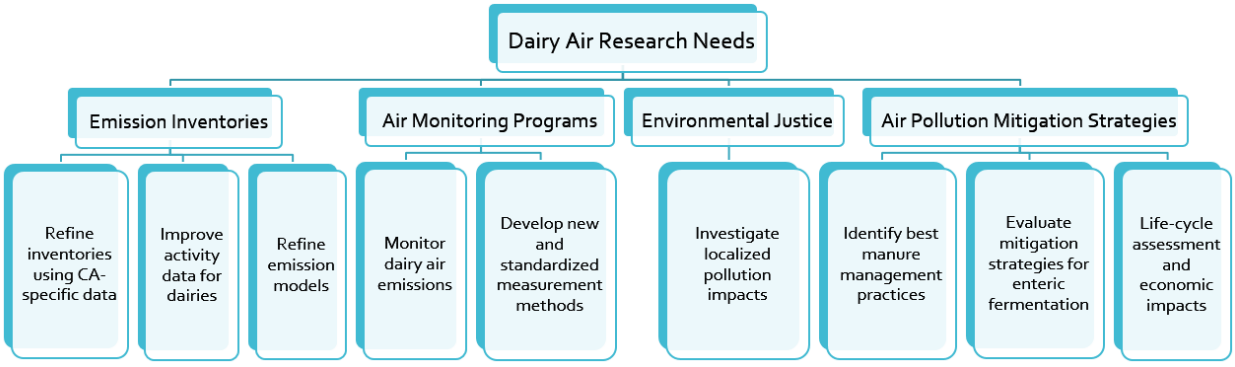
EXECUTIVE SUMMARY

The Dairy and Livestock Subgroup #3 (SG#3) was formed to identify dairy research needs that could improve the knowledge on the accuracy of greenhouse gas (GHG) and other air pollutant emissions from California dairies, potential GHG emission reductions and air quality impacts (positive and negative) from the implementation of methane (CH_4) mitigation strategies, and potential GHG emission reductions for enteric fermentation including short- and long-term impacts of potential reduction measures on dairy product quality and consumer acceptance, animal health and welfare, dairy economics, water quality, and air quality. The dairy industry has been steadily reducing the GHG emissions per gallon of milk produced through research and improvement in genetics, nutrition, and many other practices. Additional research is needed to accelerate that improvement toward the goals of SB 1383.

SG#3 held a series of public meetings to brainstorm and discuss past and ongoing research in the dairy and livestock sector. Through this process, SG#3 identified knowledge shortfalls and dairy air research needs in California. SG#3 subsequently implemented the Request for Ideas (RFI) solicitation process to conceptualize and develop this *Dairy Air Research Prospectus* with broad range of research ideas gathered from working group members, communities, researchers, government agencies, industry stakeholders, and other groups, organizations, and individuals. These ideas were compiled and made into a set of recommended project concepts that would lead to improved understanding of dairy air emissions and effective air pollutant emission reduction and mitigation strategies that would satisfy the goals of Senate Bill 1383 (SB 1383). These recommended project concepts are shown below:

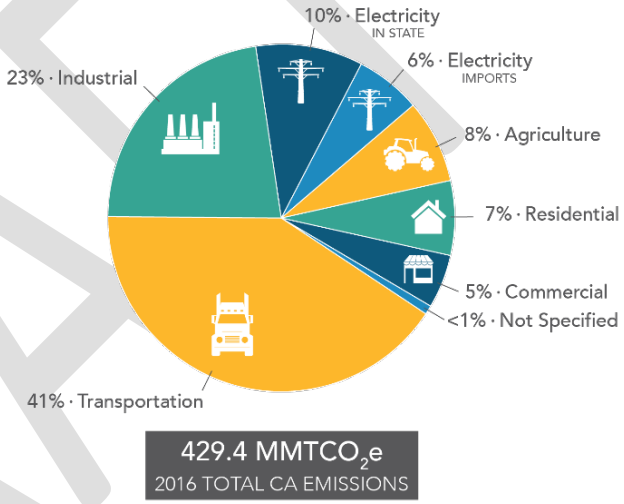


INTRODUCTION

IMPORTANCE OF CALIFORNIA'S DAIRY INDUSTRY

California is the national leader in milk production, and the dairy industry has been an integral part of the State's economy. According to the California Agricultural Statistics Review 2016-2017, milk and dairy products produced the largest annual revenues (approximately $6.07 billion) among all agricultural commodities. Its tremendous contributions to the labor market also make California dairy an indispensable sector with a profound impact on the State's development.

Currently, the agricultural sector contributes to approximately 8% of California's total GHG emissions, and approximately 57% of California's total CH_4 emissions. Of the 57% CH_4 contribution, 10.9 MMT CO_2e per year is attributed to enteric fermentation from cattle, and 10.0 MMT CO_2e per year is attributed to dairy manure management.



Breakdown of GHG emissions in California (California's 2016 Statewide GHG Emission Inventory, 2018 Edition).

The dairy industry has been steadily reducing the GHG intensity of milk through research and improvement in genetics, nutrition, and many other practices. Additional research is needed to accelerate that improvement toward the goals of SB 1383. Dairy farmers have applied research to improve efficiencies and production for decades, which highlights the importance of research needed in the dairy industry to effectively achieve results in practice. The carbon footprint per billion pounds of milk produced in 2007 was only 37% of 1944 levels39. Dairies today continue their GHG reductions using a combination of new and old mechanisms. Since the passage of SB 1383 California dairies have been implementing practices to reduce CH_4 emissions from manure with great success. It is important that California continues to demonstrate dairies' capabilities to achieve CH_4 emission reductions, and to lead dairy research that will help achieve similar CH_4 emission reductions on a global scale.

LEGISLATIVE ACTIVITIES TO COMBAT CLIMATE CHANGE

The California Legislature has repeatedly demonstrated commitments to improve the air quality and to reduce greenhouse gas (GHG) emissions through the passage of multiple bills. In September 2014, Senate Bill 605 (SB 605, Lara, Chapter 523) was passed and signed into law, which designated the California Air Resources Board (CARB) to develop a comprehensive strategy that would reduce emissions of short-lived climate pollutants (SLCPs) within the State. Subsequent establishment of Senate Bill 1383 (SB 1383, Lara, Chapter 395) in September 2016 has required CARB to approve and implement comprehensive SLCP emission reduction strategies to achieve reduction of CH_4 by 40%, hydrofluorocarbon gases by 40%, and anthropogenic black carbon by 50% below 2013 levels by 2030. SB 1383 included explicit requirements to reduce CH_4 emissions from landfills and the dairy and livestock sector. In addition, Assembly Bill 1496 (AB 1496, Thurmond, Chapter 604) approved in 2015 has required CARB to undertake monitoring and measurements of high emission CH_4 hot spots in California, which has implication for dairy operations.

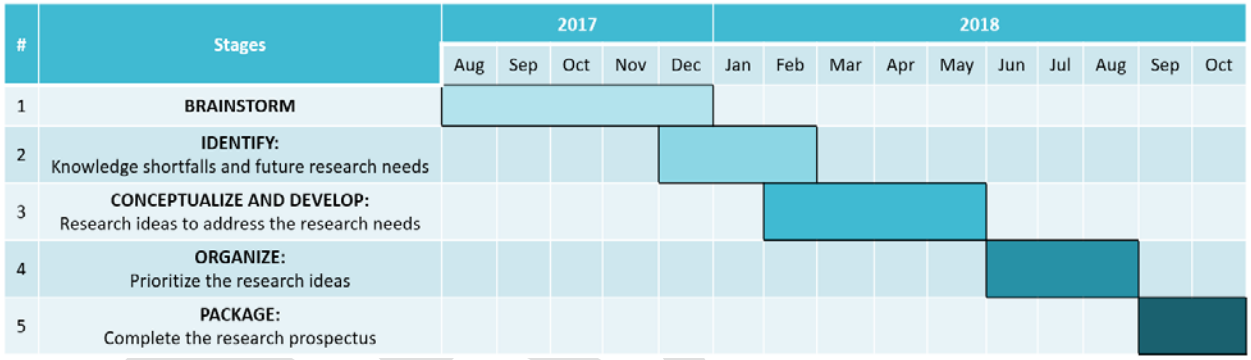
Signing ceremony of SB 1383.

OBJECTIVES OF DAIRY AND LIVESTOCK WORKING GROUP: SG#3

In keeping with the requirements under SB 1383, CARB, the California Department of Food and Agriculture (CDFA), the California Energy Commission (CEC), and the California Public Utilities Commission (CPUC) assembled a Dairy and Livestock Working Group in 2017 to identify and address technical difficulties, market barriers, and regulatory challenges to facilitate the development of dairy and livestock CH_4 emission reduction measures with broad range of stakeholders. Furthermore, three subgroups were created to effectively address key questions related to dairy manure management and enteric fermentation.

The purpose of the SG#3 was to identify and prioritize dairy research needs to improve our knowledge on the accuracy of GHG and other dairy associated air pollutant emissions, the potential GHG emission reductions and air quality impacts from the implementation of CH_4 mitigation strategies, and the feasibility of enteric fermentation emission reduction strategies in the agricultural sector. Product quality, consumer acceptance, animal health and welfare, dairy economics, and water quality were identified as critical parameters that must also be evaluated to effectively achieve the goals of SB 1383.

The SG#3 held a series of public meetings during which the members brainstormed and discussed about past and ongoing research in the dairy and livestock sector, and identified knowledge shortfalls and future dairy air research needs. The SG#3 also implemented the Request for Ideas (RFI) solicitation process to conceptualize and develop the *Dairy Air Research Prospectus* that encompassed a broad range of research ideas gathered from the working group members, communities, researchers, government agencies, industry stakeholders, and other groups, organizations, and individuals.



SG#3 activities between August 2017 and October 2018.

The compilation of these information, along with inputs from Subgroup #1 and #2 was incorporated into *the Dairy Air Research Prospectus* to guide California's funding agencies and organizations prioritize future dairy research projects.

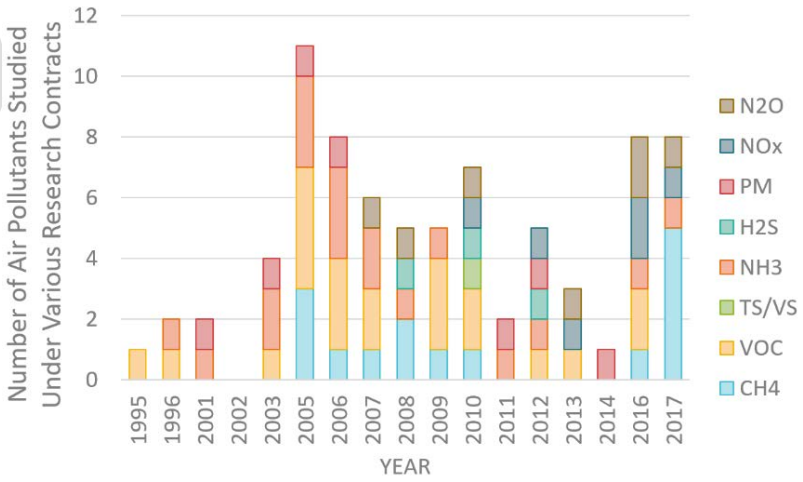
SECTION 1: PREVIOUS DAIRY AND LIVESTOCK GHG AND AIR QUALITY RESEARCH IN CALIFORNIA

FEDERAL AND CALIFORNIA ACTIONS AND PERSPECTIVES

Air releases of hazardous substances from animal waste at farms (e.g., dairies) were regulated at the federal level by the Clean Air Act. Since the early 20th century, air pollution emission research for livestock farms has been ongoing, including measurement and evaluation of reactive organic gas (and CH_4) emissions from animal ruminants. In 2003, the National Academy of Sciences (NAS) recognized the significant variabilities in the agricultural activities and air pollutant emissions, and advocated for the development of guidelines that would aid in better characterization and estimation of air pollutant emissions from various livestock farm operations. This in turn set priorities for both short- and long-term air emission research in the U.S. and led to the adoption of Senate Bill 700 (SB 700, Florez, Chapter 479) in 2005 that would enforce permitting actions in California to reduce air pollutant emissions from agricultural operations in efforts to meet the National Ambient Air Quality Standards (NAAQS) for particulate matter (PM) and ozone (O_3).

SUMMARY OF PAST RESEARCH FINDINGS

Experimental measurements and model simulations have been used to determine the environmental impacts of dairy and livestock related air pollutants in California that are typically emitted at various stages of their operations. Air pollutants include GHGs, such as CH_4 and nitrous oxide (N_2O), and other important air quality drivers such as volatile organic



Number of California dairy research studies on various air pollutants associated with dairies.

compounds (VOCs), ammonia (NH_3), hydrogen sulfide (H_2S), oxides of nitrogen (NO_x), and PM[1-8]. By 2017, more than 40 research projects have been funded in California by government agencies, non-government organizations, and industry, accumulating over $8 million in funding. Overall, dairy and livestock research efforts throughout the nation contained a variety of topics including, but not limited to:

- Estimating air pollutant emission rates and calculating emission factors to evaluate and improve emission inventories[2, 9-11],
- Developing process-based emission models[12-14],
- Assessing impacts on regional air quality and climate change[1, 5, 15-17], and
- Investigating various mitigation practices for air pollution emission reductions[18-20].

Despite considerable variabilities in when, where, and how much air pollution is emitted by California dairies[21, 22], previous studies have determined that:

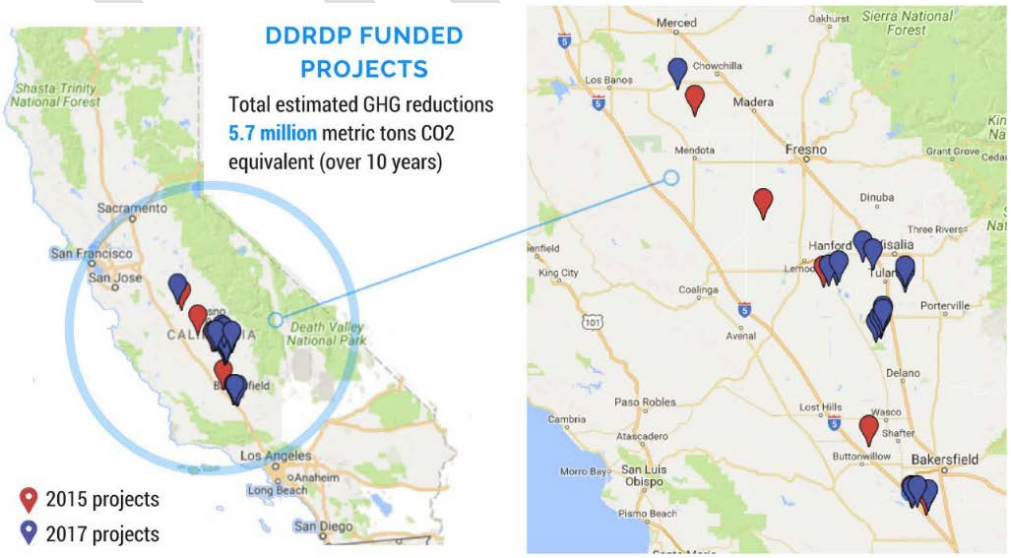
- Dairy and livestock operations are one of the largest emission sources of GHG (and other air pollutants such as NH_3) in some regions of California such as the San Joaquin Valley (SJV)[23, 24],
- Emission inventories appeared to underestimate CH_4 and NH_3 emissions from dairies in California[25-28],
- Process-based emission models were incomplete and needed additional improvements to better represent real-world conditions (e.g., chemical, biological, and physical processes that affect emissions) and improve quantitative estimation of air pollutant emissions from dairies in California[13, 29, 30],
- Dairy-related air measurements are spatially sparse and lack temporal resolution in California,
- Potential mitigation options are available in California, but need further evaluation to ensure that there are no significant public health and environmental dis-benefits[31-36], and that the strategies are cost-effective[37], and
- Regional air quality models have been used to evaluate the impact of dairy-related VOCs and NH_3 emissions to secondary air pollutants that are formed in the SJV (e.g., PM and O_3)[16, 38], which highlights the importance of further research that would lead to a comprehensive air pollution emission reduction and mitigation strategies in California.

SECTION 2: CURRENT DAIRY AND LIVESTOCK GHG AND AIR QUALITY RESEARCH IN CALIFORNIA

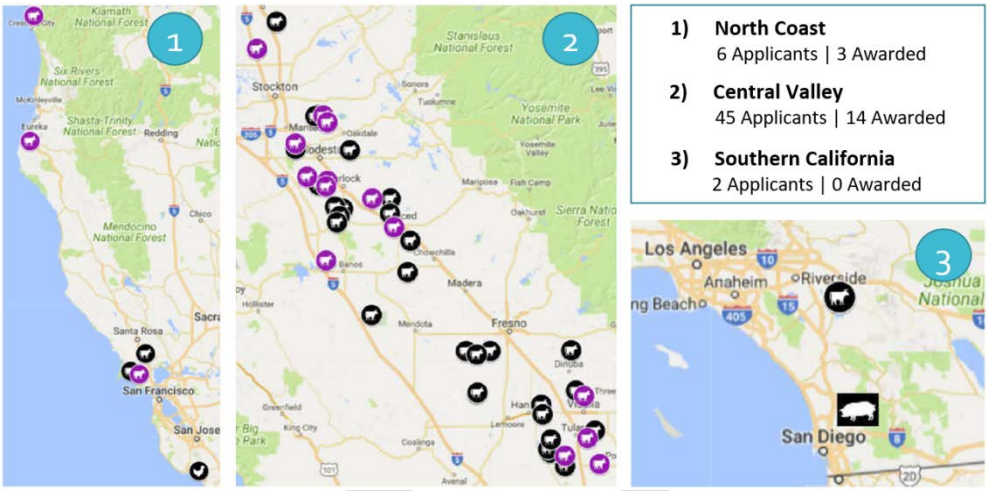
The California Legislature has invested considerable resources in various government agencies to reduce GHG and air pollution emissions associated with dairy operations. As a result, many dairy air research projects are in progress.

CDFA SPONSORED DAIRY INCENTIVE PROGRAMS AND RESEARCH PROJECTS

CDFA currently is managing two major incentive programs related to dairy GHG emission mitigation: Dairy Digester Research & Development Program (DDRDP) and Alternative Manure Management Program (AMMP). DDRDP provides financial assistance for the installation of dairy digesters in California, while AMMP incentivizes the development and implementation of non-digester manure management practices to reduce GHG emissions. CDFA received $99 million from the Greenhouse Gas Reduction Fund in 2017 (AB 109 – Budget Act of 2017), and planned to allocate $61-$75 million and $19-$33 million for DDRDP and AMMP in 2018, respectively. The figures below show the geographical distribution of CDFA funded dairy digesters and AMMP application locations in the State.



Location of DDRDP Funded Projects in California. Source: CDFA DDRDP Report of Funded Projects (2015-2017), https://www.cdfa.ca.gov/oefi/ddrdp/docs/DDRDP_Report_February2018.pdf



Location of AMMP Funded Projects in California. Source: SB 1383 Subgroup #1 Presentation, https://www.cdfa.ca.gov/oefi/AMMP/docs/SB1383_Subgroup1-Presentation.pdf

Under DDRDP, researchers are conducting a study on converting manure to reduce GHG emissions, minimize environmental impacts, and enhance the economic feasibility of dairy operations. The project is focused on the use of hydrodynamic cavitation capable of converting a large amount of manure into more stable and sterile soil amendments with predictable nitrogen mineralization responses that reduce GHG emissions.

CDFA and stakeholders also funded a research project focusing on the evaluation of AMMP practices. The researchers aim to quantify the baseline emissions at six selected dairy farms in the SJV which received an AMMP grant. Various air pollutants (including CH_4, N_2O, NO_x, VOCs, NH_3, H_2S, and PM) will be measured before the implementation of AMMP practices. CARB is also coordinating with CDFA and the researchers to conduct post AMMP implementation studies (described in section below). The project also will evaluate existing dairy air emission modeling tools and identify and recommend an appropriate model for further validation using experimental data collected from the study.

Another ongoing research effort supported by CDFA and California's dairy industry is to comprehensively investigate the effect of solid-liquid separation technologies on reducing CH_4 emissions from dairy manure lagoons. The researchers will collect and analyze liquid manure water samples from six selected dairy farms equipped with different types of separators to examine volatile solids (VS) removal efficiency and CH_4 reduction potential.

Under the Small Dairy Climate Change Research program, CDFA recently initiated a project to conduct economic evaluations of strategies for CH_4 emission reduction effectiveness and appropriateness in small and large California dairies. Authorized by the Budget Act of 2017-18, this study will contribute to the Small Dairy Climate Action Plan.

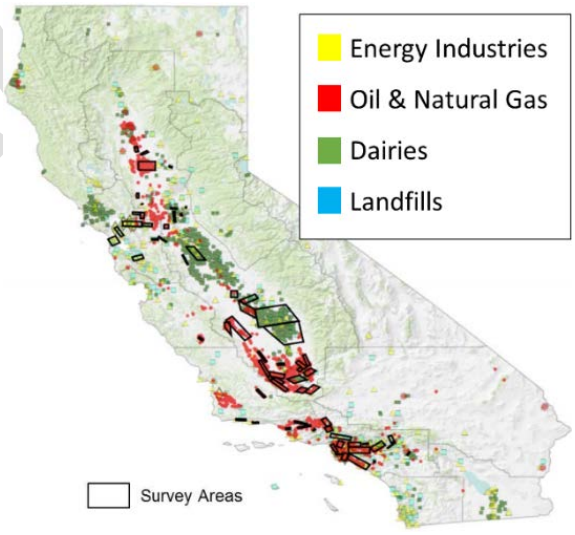
CARB SPONSORED DAIRY RESEARCH PROJECTS

CARB currently is working with the researchers to characterize California-specific cattle feed rations and to improve the modeling of enteric fermentation for California's GHG emission inventory as the Cattle Enteric Fermentation Model developed by the U.S. Environmental Protection Agency (EPA) currently does not represent the variability among different regions throughout the nation. The objective is to create a set of empirical mathematical models for estimating enteric CH_4 emissions from California's cattle using California-specific inputs.

CARB is also taking efforts to characterize physical and chemical properties of manure in California dairy systems to improve GHG emission estimates. The researchers plan to conduct real-world survey of manure management pathways at representative dairy farms. Representative samples of manure will be taken from each manure pathway to determine the nutrient flow at each stage of management. Results will be compared to U.S. EPA's assumptions about VS in manure management systems modeled according to farm size, temperature, and other factors related to CH_4 production.

In addition, CARB is funding a research study on the strategies to reduce CH_4 emissions from enteric and lagoon sources. The project will conduct literature review, database analysis, and life cycle assessment to evaluate the potential and feasibility of using additives in animal feed and manure storage lagoons as a strategy to reduce CH_4 emissions from livestock operations.

As part of the AB 1496 research efforts, CARB is collaborating with NASA Jet Propulsion Laboratory to conduct a large-scale statewide aerial CH_4 survey to identify and mitigate CH_4 super emitters in California using an imaging camera onboard the aircraft. The survey will capture CH_4 sources in all important sectors including dairies. CARB has also contracted with Scientific Aviation to perform airborne measurements to quantify facility-level CH_4 emission fluxes throughout the State using small planes equipped with sensitive and real-time monitors. This project will estimate CH_4 emission rates from large diffused sources such as dairies.



AB 1496 Airborne Campaign Area. Source: https://ww2.arb.ca.gov/our-work/programs/methane/ab1496-research

More recently, CARB funded a companion study on AMMP practices which is intended to compare the air emissions from pre- and post-AMMP dairies to quantitatively understand the effectiveness of different AMMP strategies on air emissions. The research project includes not only on-site measurements, but also a scenario-based air quality forecasting model to understand the impact of AMMP practices on local and regional air quality. Specifically, the concentrations of PM and O_3 in the SJV through 2050 will be predicted using the air pollutant emission monitoring results.

UCD Mobile Air Quality Laboratory that will be deployed for pre- and post-AMMP research studies.

The modeling effort will develop a spatial understanding of PM and O_3 formation in the SJV to ensure minimal environmental impacts of various AMMP implementation scenarios. It will also examine the complex interactions of air pollutant emissions within the SJV by conducting sensitivity analyses comparing business-as-usual emissions (pre-AMMP) with post-AMMP scenarios. This research will assess the air pollution mitigation strategies for dairy operations in California holistically.

UNIVERSITY OF CALIFORNIA SPONSORED DAIRY RESEARCH PROJECTS

The University of California Office of the President (UCOP) funded a group of researchers to study the climate impact of manure management from California dairies. The researcher will measure, model, and estimate the emissions of GHGs and other air pollutants from dairies using a multi-tiered approach (including field sampling, aerial measurements, and process-based modeling). Specifically, the researchers will construct a high-resolution map of CH_4 and N_2O emission sources (including dairies) in the SJV, measure emissions and drivers of CH_4 and N_2O from manure management, conduct mobile measurements of GHGs at farm level, and estimate emission fluxes using dispersion modeling. The project is expected to start its pilot study in the summer of 2018.

SECTION 3: FUTURE DAIRY AND LIVESTOCK GHG AND AIR QUALITY RESEARCH NEEDS IN CALIFORNIA

IDENTIFYING KNOWLEDGE SHORTFALLS AND RESEARCH NEEDS

SG#3 brainstormed and identified four major dairy air research areas in which California has knowledge shortfalls and research needs. These topics were presented at the public meeting on December 18, 2017 (https://www.arb.ca.gov/cc/dairy/dsg3/dsg3.htm). To further narrow the scope of work, SG#3 initiated a Request for Ideas (RFI) solicitation process to gain inputs from working group members, communities, researchers, government agencies, industry stakeholders, and other groups, organizations, and individuals. This process collectively gathered information to help the industry and various funding organizations prioritize the most important research needed to achieve the goals of SB 1383 while promoting a transparent and collaborative environment. The concept of RFI process was introduced during the public meeting on February 28, 2018. CARB hosted the RFI Submission Docket under the Dairy and Livestock SG#3 website (https://www.arb.ca.gov/cc/dairy/dsg3/dsg3-rfi.htm), which was made public in March 2018. Outreach efforts were extended to the SJV Ag Tech Group, California Dairy Research Foundation, CDFA, CEC, CPUC, U.S. Department of Agriculture (USDA) Agricultural Air Quality Task Force, USDA Sustainable Dairy Project Team, University of California, California State University, and more.

The official RFI submission process started on March 15, 2018 and ended on May 31, 2018. All potential contributors had the opportunity to submit ideas under one or more of the knowledge shortfalls and research needs identified during the earlier activity of SG#3. The RFI Submission Guideline (https://arb.ca.gov/cc/dairy/dsg3/rfi-submission-

CALIFORNIA AIR RESOURCES BOARD

Request for Ideas (RFI) for Dairy Research

Subgroup #3 (Research Needs, Including Enteric Fermentation)

The Dairy and Livestock Subgroup #3 (Research Needs, Including Enteric Fermentation) is requesting RFI submissions to define research needs and knowledge shortfalls that can be addressed to facilitate the reduction of dairy and livestock methane emissions. All interested parties are invited to submit research ideas that can help California effectively achieve SB 1383 goal

RFI submissions will be pre-screened for completeness and appropriate content. Pre-screened submissions will be reviewed by Subgroup #3 committee members before they are drafted into a Dairy Air Research Prospectus. The completed prospectus will be used to provide recommendations for the most feasible research needed to address SB 1383 goals under each of the knowledge shortfalls identified previously by Subgroup #3.

Completed RFI Submission Forms are to be sent to SLCP@arb.ca.gov. The deadline to submit is **May 31, 2018 at 5:00 pm (PDT)**.

Interested parties are encouraged to learn more about the RFI submission process by visiting the Subgroup #3 website.

Disclaimer: There are no intentions from any partners or affiliations in awarding a contract for funding based on RFI submissions, and participation in this RFI solicitation process does not translate to future funding, nor lack thereof.

More Information

Listserv notification of RFI Solicitation and announcement of RFI Submission Docket

guideline.pdf) was provided to the public in order to help participants better understand the purpose of the RFI solicitation, general submission procedure, and submission requirements. In addition, the RFI Submission Evaluation Guideline was created and discussed by SG#3 members in order to develop evaluation strategy and criteria.

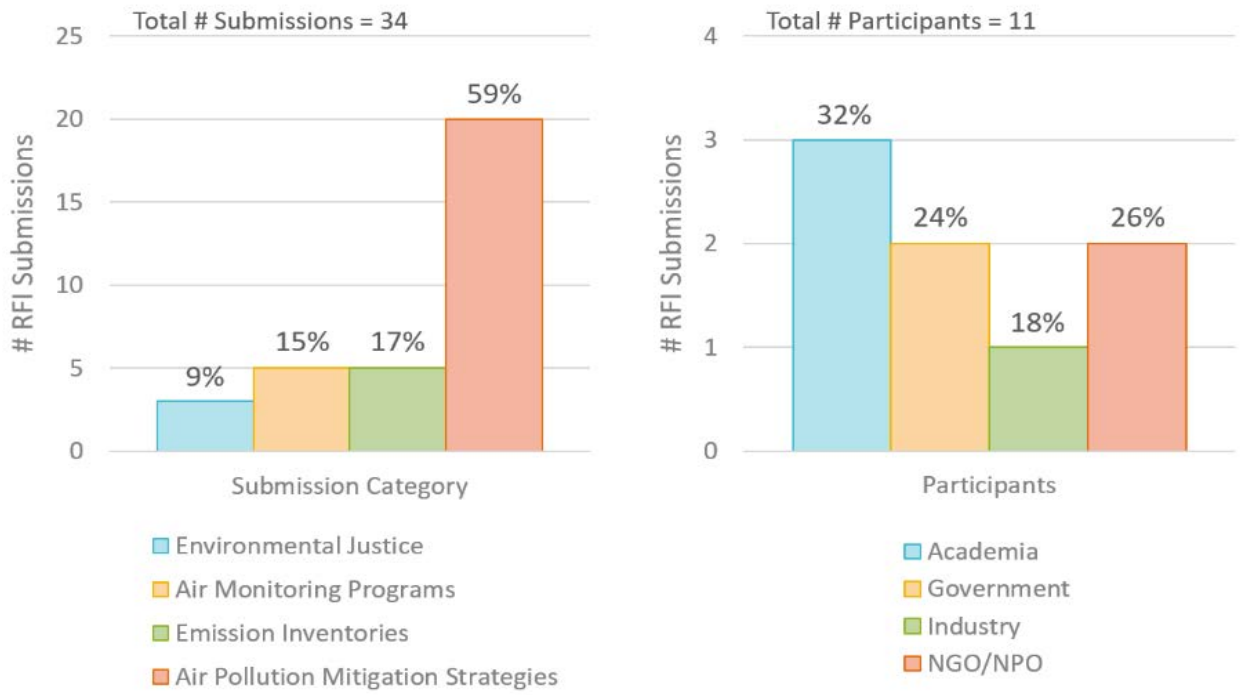
RFI EVALUATION PROCESS

All RFI submissions were first reviewed for completeness and appropriateness by CARB staff. This initial review process removed unqualified submissions that did not follow the RFI Submission Guideline developed by SG#3. This led to the removal of submissions that included unrealistic demands, inappropriate language, and those that did not pertain to the SB 1383 CH_4 emission reduction objectives.

The SG#3 members were grouped into two reviewing committees based on the evaluation strategy regarding member selection options, which was discussed at the public meeting on May 14, 2018. This promoted thorough review of each RFI submission in a timely manner. The committee members were distributed to reflect similar composition of experts in each group, and were responsible for evaluating all of the RFI submissions that were assigned to the respective group. Personally identifiable information was removed from all of the RFI submissions to prevent any potential biases. The members of the reviewing committees were not allowed to evaluate their own submissions. To maintain a consistent review of individual RFI submissions, the SG#3 members used a set of common criteria which was designed based on the RFI evaluation criteria, which included environmental impacts, industry impacts, policies/regulations/programs, and feasibility. In order to promote consistency in the evaluation of RFI submissions, clear definitions for the scoring criteria were established before the RFI submissions were sent to the reviewing committee members.

RESULTS FROM OPEN RFI PROCESS

There were 34 RFI submissions which passed the completeness review conducted by CARB staff. RFI submitters included academic institutions, non-governmental organization and non-profit organization, government agencies, and industry. Overall, 11 entities participated in this RFI process. These RFI submissions represented a variety of perspectives, which allowed SG#3 to holistically evaluate important dairy air research concepts that made the result of RFI solicitation more comprehensive. There were variabilities in the scores among different

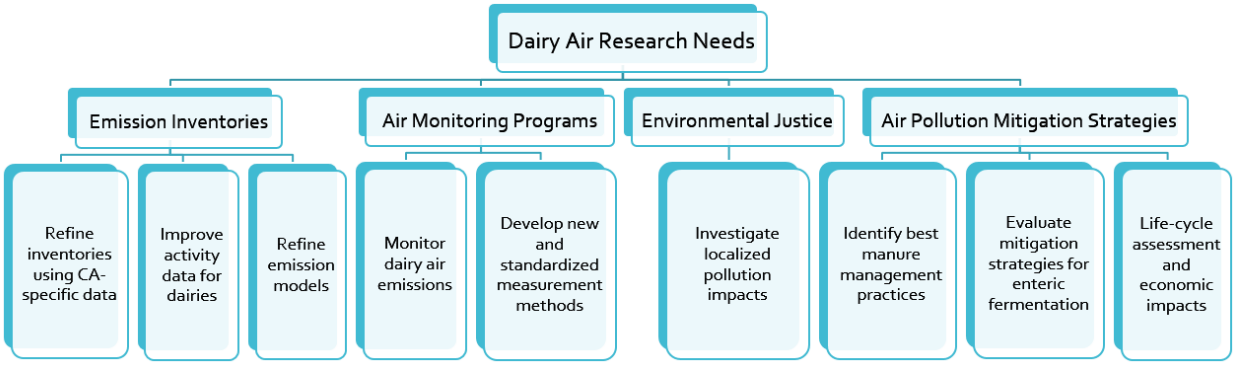


Statistics on the breakdown of RFI submissions.

submissions, which is an indication of how different each of the reviewing committee members viewed the submissions, however, the process allowed SG#3 members to group and prioritize the research needs to better measure and reduce CH_4 from dairies in the state. The submissions were grouped into "project concepts" under respective knowledge shortfall and research need categories identified by SG#3. Through this process, SG#3 was able to develop achievable dairy air research prospectus that incorporates expert assessment of holistically gathered dairy air research ideas that would help achieve SB 1383 goals.

RECOMMENDATIONS

The 34 RFI submissions were grouped into nine major project concepts based on objectives, methods, and evaluation procedures. Specificity of each concept is summarized below:



Project concepts that address dairy air research needs based on the RFI submissions.

EMISSION INVENTORIES

Refine inventories using CA-specific data: California utilizes national dairy data to develop CH_4 and VOC emission inventories. However, dairies and manure management strategies in California are often different, which significantly affects the emission rates of air pollutants. Existing inventories needs further refinement using California specific data to reflect realistic conditions.

Solution: Conduct a comprehensive measurement campaign to quantify GHG emissions from the variety of dairy and livestock operations in California that would develop a more accurate understanding of dairy air emissions to guide future CH_4 emission reduction strategies.

Improve activity data for dairies: Comprehensive information on dairy activities are necessary to help California regulators and rule makers realize the most feasible CH_4 emission reduction and mitigation strategies. However, detailed dairy activities data is very limited in California (e.g., feed types, manure collection/storage/treatment/use, housing facilities, and maintenance). Activities significantly affect air pollutant emissions, and therefore must be evaluated to the full extent possible in order to further refine CH_4 and VOC emission inventories.

Solution: Conduct a large and comprehensive dairy activities survey in California, which includes information such as feed types, manure collection/storage/treatment/use, housing facilities, and maintenance.

Refine dairy emission models: Parameterization of dairy emission models have relied on limited data that are generally specific to evaluated dairy farms. Additional stress testing and model verification measures must be made to improve CH_4 and VOC emission inventories using a more holistic approach that cater to California's diverse dairy operations.
Solution: Evaluate various dairy operations using a comprehensive and standardized strategy to update, calibrate, and validate emission models must be developed.

AIR MONITORING PROGRAMS

Monitor dairy air emissions: Dairy air emissions vary based on on-site activities and seasonal changes that affect the environment. Past dairy research in California focused on temporary unresolved datasets that are incomplete. Long-term air monitoring at various dairies must be made to fully understand the impact of changing activities and the environment on dairy air pollutant emissions.
Solution: Install long-term air monitors at various dairy facilities to study dairy air emissions before and after the implementation of various manure manage practices to identify the most effective and economically viable manure management strategies in California.

Develop new and standardized measurement methods: It is crucial to develop new technologies for improved measurements of air emissions from dairies, and create uniform testing procedures of air emission characterization for different dairy operations.
Solution: Investigate dairy air emissions using new technologies and standardized methods will better inform process-level air pollutant emission models, spatiotemporal variabilities of emissions, and lead to further refinement of CH_4 and VOC emission inventories.

ENVIRONMENTAL JUSTICE

Investigate localized pollution: Dairies contribute to air pollution in California that affects the ambient concentrations of criteria air pollutants such as ozone and particulate matter (various dairy operations affect air quality differently). In addition to evaluating California's changing dairy operations for CH_4 emission reductions, they must also be evaluated to ensure that disadvantaged communities and dairy workers are not affected by additional air quality dis-benefits.
Solution: Conduct evaluation of various environmental effects, especially near environmental justice communities, from existing and changing dairy operations (e.g., digesters, AMMP, on-site transportation) to fully realize the effectiveness of various CH_4 emission reduction strategies.

AIR POLLUTION MITIGATION STRATEGIES

Identify best manure management practices: There are number of manure handling and treatment options in California that are economically viable for varying size of dairies. However, not all manure management strategies (such as anaerobic digester, alternative manure management practices, and manure lagoon additives) have been fully evaluated for their effectiveness in reducing CH_4 emissions while proving its economic feasibility.
Solution: Quantify air pollutant emissions of viable manure management strategies in California that have not yet been incorporated in existing contracts and research studies.

Evaluate mitigation strategies for enteric fermentation: There have been ongoing interests in understanding the effectiveness of dairy feed additives to reduce CH_4 emission from enteric fermentation. Preliminary studies show repeatable CH_4 emission reduction from enteric fermentation, but despite being vetted for FDA approval, there is a lack of comprehensive life cycle assessment that would address the additive's impact on dairy cows' long term health, dairy products, consumer acceptance, dairy economics, microbial activities in manure, condition of manure applied croplands, and plant growth/health.
Solution: Conduct full impact assessment of dairy feed additive to ensure proper application without negative side effects.

Life-cycle assessment and economic impacts: CH_4 mitigation strategies for manure and enteric fermentation must be holistically evaluated (from cradle to grave) including their economic impacts on dairy and agricultural industry. While CH_4 emission reduction is the primary goal for SB 1383, dairies in California are integral part of the larger economy and its sustainability is critical.
Solution: Identify the most environmentally and economically feasible CH_4 mitigation strategy that also leads to effective CH_4 emission reduction.

OTHER CONSIDERATIONS

The project concepts as described above can also support the recommendations from Subgroup #1 and Subgroup #2.

- Scientifically sound research findings are a key component of robust outreach and education program for dairymen.
- Research and development is critical for advancing new technologies to reduce CH_4 emissions.

- Research demonstration about value-added products from manure and digestate can help identify promising technologies/practices and evaluate the economic impacts/cost-effectiveness.

The cross-over issues with Subgroup #1 and Subgroup #2 needs to be addressed (to be continued...)

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