STATE OF CALIFORNIA

# AIR RESOURCES BOARD

MEETING OF THE

# RESEARCH SCREENING COMMITTEE

**September 6, 2023**
**10:00 a.m.**

**Air Resources Board**
**Research Division**
**Cal/EPA Building**
**1001 I Street**
**Sacramento, CA 95814**
**(916) 445-0753**

**CALIFORNIA AIR RESOURCES BOARD**

**Research Screening Committee Meeting**
**Cal/EPA Headquarters Building**
**1001 I Street**
**Sacramento, California 95814**
**(916) 445-0753**

**September 6, 2023**
**10:00 a.m.**

**AGENDA**

2. “Airborne Flux Measurement of Volatile Organic Compounds and Oxides of Nitrogen in California,” University of California, Berkeley, $700,000, Contract No. 20RD003 *40*

3. “Decision Drivers to Facilitate Lower-Polluting Product Choices by Consumers,” University of California, Los Angeles, $200,000, Contract No. 20RD008 *46*

4. “Strategies for Incentivizing High-Occupancy, Zero-Emission, New Mobility Options,” University of California, Berkeley, $700,000, Contract No. 19RD009 *50*

VI. Other Business

1. Update on Research Planning

**CALIFORNIA AIR RESOURCES BOARD**

**Research Screening Committee Meeting**
**Cal/EPA Headquarters Building**
**1001 I Street**
**Sacramento, California 95814**
**(916) 445-0753**

**April 26, 2023**
**10:00 a.m.**

**MINUTES**

**Research Screening Committee Members in Attendance via Teleconference**
Tim Wallington
Roya Bahreini
Francesca Hopkins
Bryan Hubbell
Mary Prunicki
Sam Silva
Aly Tawfik

I. Approval of Minutes of Previous Meeting

February 10, 2023

II. Discussion of Research Proposals

1. "Impacts of Air Pollution on Life Expectancy across Multiple Generations: Race, Ethnicity and Vulnerability Perspectives," University of California, Berkeley, $500,000, Proposal No. 2871-305

Staff informed the committee that the proposal had gone through additional review by the California Department of Public Health and the Office of Environmental Health Hazard Assessment (OEHHA). Staff also noted that Dr. Josh Apte from the University of California, Berkeley is being added to the project to provide his expertise on investigating the effects of particulate matter 2.5 (PM2.5) on life expectancy.

Overall, the committee was supportive of the proposal and expressed that it was a novel and important study. Staff provided further clarifications on the methodologies and techniques used in the proposal. The committee had the following comments:

- For Task 5, a suggestion was made to add all cause life expectancy by census tract as a layer to GIS maps.

- A recommendation was made to incorporate additional expertise on life expectancy analysis in the project, for example expertise of investigators such as Arden Pope or Francesca Dominici.
- It was recommended that the terminology, specifically the definition and use of 'generation', be revised or better defined in the proposal.
- A suggestion was made to provide further clarification of how chronic conditions, comorbidities, and other covariates will be used and analyzed for the health analyses.

Motion: Move to recommend that California Air Resources Board (CARB) accept the proposal subject to the inclusion of revisions based on comments from staff and the committee.

The committee approved the motion.

2. "Long-Term Chemical Characterization and Source Apportionment of PM2.5 in the San Joaquin Valley," University of California, Davis, $950,000, Proposal No. 2872-305

   Overall, the committee was supportive of the proposal and noted the importance of this work. The committee had the following comments:

   - The principal investigator (PI) hasn't used the sensor technology before. This is a minor comment, since the PI has well-established academic record in this field.
   - Since PM2.5 in the San Joaquin Valley is crucial to local communities, it is recommended that the PI add possible collaborations with local communities.
   - Request the add more details about:
     - How they separate wildfires from prescribed fires?
     - Can they identify VCPs (volatile chemical product) factors from the measured dataset?

   Motion: Move to recommend that CARB accept the proposal subject to the inclusion of revisions based on comments from staff and the committee.

   The committee approved the motion.

III. Other Business

1. Update on Research Planning

Research staff provided the committee members an update on current research planning activities. The Research Division recently released its funding year 2023-2024 projects for solicitation. Staff shared a slide with the committee members listing the projects out for solicitation which included:

- Understanding the Air Quality Impacts of Wildfires and Prescribed Burns in Urban Environments of California ($600K)
- Development of Health Analysis Methodology for Natural and Working Lands Management Scenarios ($550K)
- Impacts of Multiple Climate Change Stressors on Health in California ($500K)
- Air Toxic Pollutants Associated Cancer Health Monetization Research ($500K)

Staff provided a brief description of the solicitation process, including that the committee members would review final proposals in at an October RSC meeting.

Staff then provided a brief update regarding the funding year 2024-2025 research planning process and that it will kick off in the near term with the yearly public comment and concept collection survey.

One committee member asked for clarification on the project titled “Development of Health Analysis Methodology for Natural and Working Lands Management Scenarios” and whether this included health impacts from wildfires versus prescribed fires. The contract manager for this project provided a brief clarification in response.

**ITEM NO.: II.1**
**DATE: September 6, 2023**

# Request for Proposal

## Air Toxic Pollutants Associated Cancer Health Monetization Research

### I. Objective

The primary objective of this research project is to develop a methodology to quantify and monetize cancer cases that are statistically estimated due to exposures to toxic air pollutants. The California Air Resources Board (CARB) currently estimates reductions in cancer risks due to regulations that reduce toxic air pollutant emissions. However, CARB has limited ability to express these benefits in monetary terms. The proposed study will develop and present a methodology that is based on the United States Environmental Protection Agency (U.S. EPA's) Office of Pollution Prevention and Toxics (OPPT)'s recent development of economic analysis methodologies for chemical risk assessments to estimate cancer risk reduction outcomes and monetary benefits for TSCA (Toxic Substances Control Act) chemicals but will adapt and enhance this methodology for California use. The methodology will be developed for health risk assessment by CARB using California methodologies for estimating air toxic cancer risks and using approaches in existing literature for adjusting excess cancer risk as discussed below. This methodology, after development and peer review, could be used for evaluating CARB air toxics control policies at the state level and if possible, at a more local level including specific communities and regions. The investigators will also determine methods to incorporate information on race and ethnicity in this project, such as disaggregation of data by racial and ethnic subgroups. Development of the methodology will help support CARB's efforts to assess the effects of toxic air pollutants and understand the benefits of cancer risk reduction statewide and in priority communities, including low-income communities and communities of color.

### II. Background

California regulates toxic air pollutants including toxic air contaminants (TAC) such as diesel particulate matter (DPM) to protect public health and reduce serious human health

risks such as cancer. CARB has adopted rules to reduce statewide or regional exposures to sources of air toxics, such as diesel exposures in commercial harbor craft regulations (1), as well as rules to reduce exposure to localized sources of air toxics including metal plating operations (2). For reductions in PM2.5, the health benefits of these rules are quantified using the methodology available on CARB's website (3). Benefits for reductions of non-PM2.5 carcinogenic air pollutants are expressed in terms of reduction in cancer risks. Cancer risk estimates are often expressed as potential cancer risks per million individuals exposed. CARB and the Office of Environmental Health Hazzard Assessment (OEHHA) develop these risk estimates using established Health Risk Assessment methodologies and inhalation cancer potency factors developed by OEHHA (3,4). At the federal level, U.S. EPA utilizes a similar methodology to determine cancer risks in their National Air Toxics Assessment program (5), where national emission inventories are used to estimate ambient air toxics associated cancer risks. U.S. EPA has also recently developed economic evaluation methodologies to quantify health benefits of cancer risk reduction in the context of TSCA implementation. While CARB estimates health benefits of avoided cases of illness and death due to PM 2.5 reductions using BenMAP analysis and a reduced form methodology called incidence-per-ton, CARB does not have a corresponding valuation methodology for cancer risk reductions associated with reduced exposures to air toxics.

The key focus for this project is the development of a methodology for the quantification and valuation of reduced cancer health hazards, including direct and indirect costs of cancer onset such as: medical treatments, hospitalization, death, and related costs. This methodology should use cancer risk estimates associated with toxic air pollutant exposures and build on economic evaluation approaches developed by U.S. EPA OPPT and used in the U.S. EPA benefit analysis of methylene chloride (6). The investigators should identify toxic air pollutants posing significant health impacts statewide and in communities for inclusion in this contract such as, but not limited to, DPM, Benzene, 1,3-Butadiene, Hexavalent Chromium, Nickel, Cadmium, Lead, Arsenic, Formaldehyde, PCBTF, and Ethylene Oxide. The methodology should build on U.S. EPA's work on chemical risk assessments and translation to socioeconomic benefits assessments as outlined in the Organization for Economic Cooperation and Development (OECD) white

papers and contributing research studies (6,7,8,9)**.** The investigators should also consider whether quantitative or qualitative methodologies are possible for estimation of cancer health outcomes for specific racial or ethnic subgroups, taking into account the social, biological and environmental factors that impact subgroup outcomes.

The main objectives for this project will be to:

- Develop a methodology to convert cancer risk estimates, developed for selected air toxics using OEHHA's methodology and specific risk reduction scenarios, to estimates of possible cancer cases based on the U.S. EPA methodology cited below. Develop a methodology for the monetization of reduced incident cancer cases for reductions in selected toxic air pollutants for specific timeframes using and combining different valuation metrics, including willingness to pay, cost of illness, value of a statistical life, and related or indirect costs such as lost productivity, and covering both fatal and non-fatal stages of cancer. Provide case studies to CARB to quantify health benefits of different scenarios of toxic risk reduction for the selected chemicals using the methodology developed for this contract. Case studies should include the timeframes for the air toxic emission reduction, exposure reduction and reduction in cancer risks. Case studies will be selected in consultation with CARB.
- Ensure that the methodologies developed are applicable to statewide reduction of air toxics risk and determine how the methodology can inform risk reduction policies at local or regional levels.
- Determine ways to include consideration of racial and ethnic subgroups in the development of data and approaches for estimation of exposures and cancer risks, and valuation of costs related to cancer cases.
- Submit to CARB a report summarizing methodologies developed to valuate cancer health outcomes and any potential limitations, including peer-reviews from at least three academic experts with relevant background in air toxics and health.

The results of this study will allow CARB and others to better assess quantitative benefits associated with cancer risk reduction from various airborne toxic control measures and

policies. This will help support CARB's efforts to assess the effects of toxic air pollutants and understand the benefits of cancer risk reduction in priority communities, including low-income communities, and communities of color.

Due to the broad scope of this project, multidisciplinary teams and multi-university teams are encouraged to apply.

## III. Scope of Work

The Contractor shall perform all tasks as described below.

**Task 1:** Literature Review on Toxic Air Pollutants and Cancer Type Assessment

The Contractor shall identify and conduct a comprehensive literature review on:

- Existing economic analysis approaches used to quantify estimates of possible cancer cases based on cancer risk estimates associated with toxic air pollutant exposure, including the U.S. EPA and OPPT documents related to benefits assessment of chemical risks and regulation of methylene chloride referenced below.
- Existing methodologies for monetizing cancer health outcomes at different stages of life for different cancer types, including a broad range of potential cancer health outcomes.

The Contractor shall also identify California-relevant toxic air pollutants for this study, which may include but are not limited to DPM, Benzene, 1,3 Butadiene, Hexavalent Chromium, Nickel, Cadmium, Lead, Arsenic, Formaldehyde, and Ethylene Oxide. Additionally, the Contractor shall identify the major cancer types (e.g., lung, liver, skin, leukemia, etc.) associated with these and other toxic air pollutants, if possible.

Deliverables: The Contractor shall submit a literature review report summarizing toxic air pollutants and cancer type assessments. This literature review report shall be submitted to the CARB Project Manager in Month 8. The literature review findings shall also be included in the draft final report (DFR).

**Task 2. Cancer Risk Conversion to Cancer Cases and Health Outcomes**

The Contractor shall develop a methodology to convert cancer risk estimates to possible cancer cases for different exposure levels to specific toxic air pollutants and over specific time periods. In consultation with CARB, the Contractor will determine the specific air toxics and the types of cancer and cancer health outcomes to be monetized. The conversion method should use existing literature identifying the relationship between toxic air pollutant exposure and cancer incidence and should take into consideration appropriate latency considerations. This methodology must be able to evaluate lifetime cancer risks and the discounted value of those risks to be applied to year specific reductions in air toxics concentrations resulting from an emissions reduction program. The Contractor shall determine which elements of the methodology can be used to evaluate multiple air toxics and which elements are unique for specific air toxics.

In developing these methods, the Contractor shall build on the methodology for estimating and valuing cancer risk reduction in CalEPA's evaluation of health benefits for regulation of methylene chloride and the studies contributing to the development of that methodology (6,7,8,9). The methodology for this objective and the following objective shall integrate the steps listed in Exhibit 1-1 of Estimated Values of Avoiding Cancer Risks by Cancer Site and Population (9). The Contractor shall use approaches in existing literature for adjusting excess cancer risk numbers as needed to reflect lower cancer exposures and effects and the life stage when the exposures occur. The Contractor shall determine the methodological steps that are similar or distinct for analyzing benefits of single air toxics or multiple types of air toxics, and converting the cancer risk estimates to cancer cases.

Deliverables: The Contractor shall submit a report discussing the methods, which convert cancer risk estimates to possible cancer cases, and the types of cancer and cancer health outcomes, for selected air toxics. This report shall be submitted to the CARB Project Manager in Month 12. This information shall also be included in the draft final report.

**Task 3.** Monetization of Cancer Health Outcomes

The Contractor shall determine the monetization for incident cancer cases for each toxic air pollutant, including willingness to pay, cost of illness, and indirect costs such as lost productivity. The monetization should include both low and high estimates that reflect statistical uncertainties in exposure, risk and valuation.

This methodology shall build on approaches in U.S. EPA's economic analysis of the health benefits of reducing methylene chloride cancer risks and related papers on socioeconomic benefits analysis and willingness to pay estimates for health endpoints developed by OECD (6,7,8, 9). The monetization shall include low and high estimates to address uncertainties.

Deliverable: The Contractor shall submit a report discussing the methods for monetization of cancer health outcomes. This report shall be submitted to the CARB Project Manager in Month 15. This information shall also be included in the DFR.

**Task 4: Peer Review**

The Contractor shall describe an independent peer review process using outside experts and explain how a review of proposed methods will be conducted. The Contractor shall submit to peer reviewers the methodology developed for quantification and monetization of cancer cases and related health outcomes of toxic air pollutants and the valuation methodology for cancer risk reductions associated with reduced exposures, highlighting key uncertainties and limitations in the analysis, where relevant. The Contractor shall seek peer review from at least three subject matter experts from academic and government health organizations.

Deliverable: The Contractor shall submit a peer review report. The peer review report including the findings of peer reviewers shall be submitted to the CARB Project Manager in Month 18. This information shall be included in the DFR.

**Task 5: Meetings, Reports, and Seminar**

The Contractor shall summarize how this project satisfies and addresses the following requirements and tasks in the DFR:

- Completion and delivery date(s) for each task.
- Submission of quarterly progress reports, a DFR, and a final report to CARB which also include the preparation of a plain-language summary of these reports for public dissemination.
- Participating in regular progress update meetings and consultation calls with CARB staff and key stakeholders.
- Preparing and providing to CARB raw data, modeled data, and all data analysis results generated through the course of the project in electronic format.

The Contractor shall submit quarterly progress reports on the template provided by the CARB Project Manager.

The Contractor shall participate in quarterly progress update meetings and consultation calls with CARB staff and key stakeholders.

In accordance with Exhibit F – Research Final Report Format, the Contractor shall prepare a DFR. The DFR outlining a step-by-step process, methods, air toxics and cancer health outcomes used, computer programs, all data (e.g., in Excel spreadsheets), analyses and analytical tools generated through the course of this project shall be submitted to the CARB Project Manager, including a plain language summary and contractors shall work with CARB to create plain-language outreach deliverables for the public summarizing results and the impact of the project (available in multiple languages).

Six months prior to the contract end date, a DFR shall be prepared by the Contractor and submitted to CARB Project Manager and to outside reviewers selected by CARB for review and comment. The DFR shall draw content from the deliverables of the preceding tasks, and include description of research methodologies, description of data collected, description of results and findings, and discussion of the peer reviewers' comments.

After receiving the comments from CARB, the Contractor shall modify and resubmit the DFR to the CARB Project Manager. This modified DFR will be subject to formal review by the Research Screening Committee (RSC). Once reviewed by the RSC, the Contractor will revise the DFR addressing the RSC comments and submit the revised final report to CARB. If CARB has additional comments on this report, CARB will notify the Contractor to make changes; otherwise, CARB will accept the revised final report. The Contractor's work plan must allow for a period of no less than six months from submittal of the initial DFR until submittal of the final report.

The Contractor shall prepare all raw data, modeled data, and all data analysis results generated through the course of the project in an electronic format to be determined in consultation with CARB.

The Contractor shall also prepare and deliver a research seminar that communicates the research project and results to a broad public audience that includes people with both academic and non-academic backgrounds.

Any peer-reviewed publications arising from this project should be made publicly available.

Deliverables: The Contractor shall submit a draft final report and final report to the CARB Project Manager. The Contractor shall present a research seminar communicating the research project and results to the public. The Contractor shall provide all raw data, modeled data, and all data analysis results generated through the course of the project.

## IV. Budget

The total proposed cost for the entire contract must not exceed $500,000. Proposals exceeding this amount will be deemed non-responsible and ineligible for award.

## V. Timeline

The total duration of this contract must not exceed 24 months. Proposals exceeding this duration will be deemed non-responsive and ineligible for award.

**References**


1. CARB Health Analyses (2021). Proposed Amendments to the Commercial Harbor Craft Regulation. https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2021/chc2021/appg.pdf
2. CARB Health Risk Assessment (HRA), The Proposed Amendments to the Airborne Toxic Control Measure for Chromium Electroplating and Chromic Acid Anodizing Operations. https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2023/chromeatcm2023/isor_appf.pdf
3. CARB's Methodology for Estimating the Health Effects of Air Pollution. Retrieved February 9, 20231, from https://ww2.arb.ca.gov/resources/documents/carbs-methodology-estimating-health-effects-air-pollution
4. OEHHA's 2015 Hot Spots guidance manual for health risk assessment: https://oehha.ca.gov/media/downloads/crnr/2015guidancemanual.pdf
5. U.S. EPA. (2018). Technical Support Document (TSD) EPA's 2014 National Air Toxics Assessment. https://www.epa.gov/sites/default/files/2018-09/documents/2014_nata_technical_support_document.pdf
6. EPA OPPT (April 2023), Economic Analysis of the Proposed Regulation of Methylene Chloride under TSCA Section 6(a).

   https://www.regulations.gov/document/EPA-HQ-OPPT-2020-0465-0175
7. Chiu, W. (2017), "Chemical risk assessment and translation to socio-economic assessments", *OECD Environment Working Papers*, No. 117, OECD Publishing, Paris, https://www.oecd-ilibrary.org/environment/chemical-risk-assessment-and-translation-to-socio-economic-assessments_a930054b-en. https://doi.org/10.1787/a930054b-en
8. OECD Org. (2023), Brochure-Surveys-of-willingness-to-pay-to-avoid-negative-chemicals-related-health-effects-SWACHE, 2023. https://www.oecd.org/environment/tools-evaluation/Brochure-Surveys-of-willingness-to-pay-to-avoid-negative-chemicals-related-health-effects-SWACHE.pdf
9. Abt Associates., (October 6, 2022), Estimated Values of Avoiding Cancer Risks by Cancer Site and Population, submitted to Existing Chemical Risk Management Division, Office of Pollution, Prevention, and Toxics, U.S. Environmental Protection Agency.

## IV. Proposal Evaluation Criteria

| **1. MINIMUM QUALIFICATIONS** | **YES** | **NO** |
|---|---|---|
| The Proposer must demonstrate expertise in economic evaluation of cancer health risks | | |
| The Proposer must have participated in at least one project involving air toxic risk assessment related to cancer, demonstrate understanding of statistical assessments of cancer health risks, and demonstrate expertise on valuation of cancer health outcomes. | | |
| The Proposer must demonstrate ability to identify California-relevant toxic air pollutants which include but not limited to DPM, Benzene, 1,3 butadiene, Hexavalent Chromium, Nickel, Cadmium, Lead, Arsenic, Formaldehyde, and Ethylene Oxide and identify the major cancer types (e.g., lung, liver, skin, leukemia, etc.) associated with these air pollutants. | | |
| The Proposer must have published research findings from at least one previous study in reputable peer-reviewed journals. | | |
| ***If minimum qualifications are NOT met, STOP HERE.*** | | |
| | | |
| ***Scoring Items*** | | |
| **2. TECHNICAL APPROACH AND WORK PLAN*** | **Points Available 35*** | **Points Awarded** |
| Proposer demonstrates their knowledge in the subject of the RFP and lays the groundwork for the actual work to be performed for this project. Proposer identifies specific techniques, instruments, software, and other notable/unique expertise to be employed in performing data collection, processing, and analysis. Proposer provides a detailed description of the overall approach and methodologies that would be utilized to accomplish the tasks listed in **Attachment 6**, Draft Standard Agreement, Exhibit A, Section III, Scope of Work. Proposer provides a concise work plan and schedule detailing how they aim to accomplish each task and sub-tasks, the responsible party for performing the task, and anticipated date of completion. Proposer demonstrates their understanding of the questions or needs that CARB is seeking to address. The technical approach and work plan are considered the heart of the proposal and will receive a high level of scrutiny. This part of the proposal will be evaluated to ensure all tasks and deliverables listed in **Attachment 6**, Draft | | |

| | | |
|---|---|---|
| Standard Agreement, Exhibit A, Section III, Scope of Work are included and responsive. | | |
| **3. EXPERIENCE** | **Points Available 20** | **Points Awarded** |
| Proposer describes experience and breadth of knowledge in performing similar studies using the technologies described in **Attachment 6**, Draft Standard Agreement, Exhibit A, Section III, Scope of Work and how skills developed in previous related work will be applied to this study. | | |
| **4. PROJECT MANAGEMENT PLAN** | **Points Available 5** | **Points Awarded** |
| Proposer provides a clear management structure and project organization. Proposer includes methods to measure proposed progress against the plan and within the project schedule. | | |
| **5. QUALITY ASSURANCE/QUALITY CONTROL PLAN** | **Points Available 10** | **Points Awarded** |
| Proposer describes quality assurance/quality control plan (QA/QC) and describes their ability to provide sound results. Proposer demonstrates their experience performing QA/QC activities and demonstrates a record of delivering well quality assured data and assuring data quality. | | |
| **6. COST** | **Points Available 30** | **Points Awarded** |
| This criterion allows staff to evaluate and compare the budgets of each proposal relative to those of its competitors. The technically qualified proposal that has the lowest cost will be given a maximum score of 30 for this criterion. | | |
| **TOTAL POINTS** | **Maximum Available 100** | **SCORE** |
| | | |

A proposal must have a total score of at least 85 points to be qualified for consideration for this contract.

* Proposals receiving less than 30 points for this criterion will not qualify for further consideration.

**ITEM NO.: II.2**
**DATE: September 6, 2023**

# Request for Proposal

## Characterization of Train Brake-Wear and Wheel/Rail-Wear PM Emissions

## I. OBJECTIVES

The objectives of this study are to characterize train brake-wear and wheel/rail-wear (BWWW) particulate matter (PM) emissions, to identify the factors that most affect those emissions for each type of train (e.g., line-hauls, switchers, and passenger trains) in California, and to help promote environmental equity for near-railroad communities. The Contractor shall develop BWWW testing cycles representing each train type by collecting their real-world or equivalent braking activity and the corresponding train operation data. The cycles should be designed for either laboratory, test track, or real-world testing to measure train BWWW PM mass and particulate number (PN) counts representing real-world train BWWW emissions. Environmental equity for near-railroad communities must be addressed by assessing current community air protection programs and policies based on train activity and emissions from this study.

## II. BACKGROUND

Exhaust PM emissions for both on-road vehicles and off-road equipment have decreased significantly over time due to stricter regulations, incentive programs, and advanced technology. Conversely, non-exhaust PM emissions (e.g., brake- and tire-wear PM) have increased and are projected to surpass the exhaust PM emissions multiple times in 2030. Non-exhaust PM emissions have become a concern due to their increased contribution to regional PM emissions and exposure in communities near traffic and freight corridors. CARB, along with other government agencies and research institutes, has investigated the impact of non-exhaust PM emissions to inform relevant programs and policies. However, current non-exhaust research characterizing emission factors (EF), PM compositions, and related potential health effects (CARB contracts 17RD012, 17RD016, and 18RD017, and Caltrans contract 65A0703) has focused only on on-road vehicles, and there is a need to expand this work to include other non-road sectors such as rail.

California has 4,981 miles of freight rail tracks and carries the second-largest freight rail carloads in the nation[1]. CARB is currently proposing an In-Use Locomotive Regulation (title 13, California Code of Regulations, sections 2478 through 2478.16) to reduce exhaust emissions, including diesel particulate matter, oxides of nitrogen, and greenhouse gas, by replacing old locomotive engines with newer cleaner models. With the expected significant reduction of the exhaust emissions from the trains, BWWW particles are expected to become the dominant sources of PM emissions from trains, similar to the projections for on-road vehicles. The extent of research on BWWW PM emissions from trains and their potential health risks in near railroad communities is scarce and insufficient for emission inventory development and health impact assessments. BWWW PM emissions from trains are not yet included in CARB's train emission inventory. Therefore, characterizing the BWWW PM emissions and train activity patterns can inform the development of BWWW PM emissions inventories and provide opportunities to assess near-railroad community exposure to these emissions.

## III. SCOPE OF WORK

The Contractor shall collect activity data during real-world train operations and design a test method to measure BWWW PM emissions for California representative types of trains: line-hauls, switchers, and passenger trains. In the development of the test method, factors potentially correlated with the BWWW emissions shall be accounted for, such as locomotive and car weights, train speed, brake and wheel/rail materials, brake and wheel technologies, etc. Real-time PM2.5 and PM10 mass, particle number, and size distribution shall be measured, and PM2.5 and PM10 filter samples for both gravimetric and composition/chemical analyses shall be collected. BWWW PM may have very different physical and chemical properties depending on the specific brake and wheel systems. The Contractor shall conduct a suite of chemical, metal, and oxidative stress analyses using the PM filter samples. The Contractor shall develop train type-specific EFs

[1] Freight rail state ranking 2019, Association of American Railroads, https://www.aar.org/wp-content/uploads/2021/02/AAR-State-Rankings-2019.pdf

and chemical profiles for BW PM and WW PM emissions. Next, to address the environmental equity of near-railroad communities, the Contractor shall assess current community air protection programs and policies based on the results from this study. The Contractor can consult environmental justice (EJ) experts or proceed via other proposed methods to understand community exposure and potential community concerns about BWWW PM emissions and suggest relevant future steps and programs.

**Task 1. Literature Review**

**Task 1a. Review of Train Duty Cycles and Non-Exhaust Emission Test Methods**

The Contractor shall conduct a comprehensive literature review on currently available train BWWW PM measurement practices, train duty cycles reflecting real-world operations, and the latest technologies of braking systems, brake friction materials, and wheel and rail materials, along with their propulsion systems. The Contractor shall conduct a comparative analysis for potential on-rail and in-laboratory test methods. The Contractor shall identify a few testing configurations designed to measure BWWW PM emissions separately, either on-rail or in the laboratory. This analysis shall identify the advantages and disadvantages of each method regarding the repeatability of emission measurements and the reproduction of real-world brake and wheel abrasion activities. The Contractor shall also obtain information about currently existing duty cycles for trains and investigate whether these duty cycles can reflect real-world train operations, such as engine load, braking frequency, and acceleration and deceleration behaviors. The Contractor shall review and summarize conventional and advanced technologies on train engines, brake technologies, and wheel systems. The Contractor shall evaluate the availability, feasibility, and influence on BWWW PM emissions of advanced technologies in the near future.

**Task 1b. Review of Train Related Exposure Studies, Research on Potential Health Impacts on the Near-Railroad Communities**

The Contractor shall conduct a comprehensive literature review on currently available studies on exposure to train emissions, both exhaust and non-exhaust emissions, and their potential health impacts on near-railroad communities. The Contractor can also

consult EJ experts, or through other proposed methods, to understand near-railroad community concerns of train emissions for both exhaust and BWWW PM.

Deliverable: A report reviewing train emissions research and studies, existing operation duty cycles, conventional and advanced engines, and brake and wheel technologies. This report shall also include reviews of recent studies of the health impact of train emissions on near-railroad communities, potential health effects, and community concerns.

**Task 2.** Identify Test Train Types and Associated Materials and Routes

**Task 2a.** Assemble a Project Workgroup

The Contractor shall organize a project workgroup (Workgroup) in consultation with CARB staff. Workgroup members may include key stakeholders such as freight and passenger rail operators, federal governmental agencies, California state agencies, and local air districts. The Contractor shall follow Workgroup guidance in planning and conducting the outlined tasks.

**Task 2b.** Market Survey of Brake, Wheel, and Rail Materials and Identify Representative Trains by Operation Types in California

BWWW PM sizes and compositions largely depend on their materials. The Contractor shall conduct market surveys of brake, wheel, and rail materials and find their market shares by material type for train types in California. The survey should be designed to collect information on the wheel and brake replacement frequencies and brake, wheel, and rail materials, technologies, and maintenance protocols/practices.

Using the survey results, the Contractor shall develop a comprehensive list of California representative train models with associated wheel and brake materials and technologies. The train models in the list should be characterized by train weight (locomotive and car weights separately) and type, commodity weight and types, and daily operation miles and frequencies. Out of the list, the Contractor shall identify the train types most prevalent in California and nominate them for activity data collection and emissions testing. These

nominated train types should be discussed with Workgroup before proceeding to the next task.

Deliverable: A report describing brake, wheel, rail, and associated technologies used for different types of trains in California.

**Task 2c.** Characterize California Train Operations

Airborne wheel/rail-wear PM will be generated during train acceleration, deceleration, and cruising due to the friction between wheels and rails, and brake-wear PM will be generated during deceleration to slow and stop trains due to the friction between brakes and wheels. Those PM emissions will vary depending on train operation characteristics by commodity type and weights, number of railcars and weight, and rail track configurations and geometry. The Contractor shall start this task by collecting and summarizing the existing California rail operation data and estimating daily, monthly, and annual activity by train types. The operation data shall include, but not be limited to, train operation hours, stops, travel miles, number of railcars hauled, average cargo weight, and operation frequencies by routes in California. The Contractor shall identify train operation factors that critically influence the BWWW PM emissions and discuss them with the Workgroup before conducting the next task.

Deliverable: A report describing operations for representative types of trains in California.

**Task 3.** Collect Train Activity Data and Develop California BWWW Testing Cycles by Train Type

Various factors will affect the BWWW PM emissions, such as train speed, train weight, train vocation, rail geometry, rail and wheel materials, brake friction materials, braking systems, and environmental factors (e.g., season, temperature, humidity, and precipitation). The Contractor shall develop a plan for collecting activity data either from California fleet representative trains or existing in-use activity data that can be used to characterize activity patterns and build BWWW testing cycles.

**Task 3a.** Collect Train Activity Data

The Contractor shall develop an activity data collection plan for braking activity and operation data. In consultation with the Workgroup, the Contractor shall identify at least one train from each train type of line haul, short-line, and passenger trains for collecting its activity data. This train activity data collection is to establish relationships between the train operation, including engine status, route geography, train speed, etc. and the braking activities.

The Contractor shall identify methods to collect train weight in real-world operations using freight and passenger logs, estimated records, or electronic weight sensors. The Contractor shall verify that the train and commodity weights are recorded correctly.

The Contractor shall install engine control unit (ECU) data loggers to acquire instantaneous engine operation data and obtain train operation data for at least four weeks. Desired ECU parameters include but are not limited to engine model and make, engine rpm, fuel rate, actual engine percentage torque, friction torque, engine reference torque, engine load, exhaust temperature, speed, and other operator control positions. In addition to ECU data, the Contractor shall collect train position data by global positioning system that will be used to calculate instantaneous train speed, acceleration, and deceleration. Train operation data include but are not limited to train weight (locomotive and car weights separately) and type, commodity weight and types, daily operation miles and frequencies, rail geometry, rail and wheel materials, brake friction materials, and braking activities.

The Contractor shall employ sensors to measure ambient temperature, humidity, and pressure. The recorded data should be used to include real-world environmental factors in the following tasks.

Deliverable: Operating activity data collected for California representative train types.

**Task 3b.** Characterize Train Activity Patterns

The Contractor shall develop a quality assurance/quality control (QA/QC) plan for analyzing the train and engine information and data collected from Task 2 and Task 3a. The Contractor shall characterize train activity patterns for each train type based on the data collected from earlier Tasks. Activity patterns shall be characterized as representative operation hours, miles, speed, acceleration, deceleration, braking events and durations, and stops per trip for each train type. The Contractor shall collect environmental factors from direct measurements or nearby weather stations. Environmental factors can be the source to characterize typical train operation conditions in California, e.g., season, temperature, and humidity, which all can play a role in airborne PM emissions.

Deliverable: Activity patterns for each California representative train type.

**Task 3c. Decide BWWW Testing Approach and Develop California BWWW Test Cycles for each Train Type**

The Contractor shall propose a BWWW testing approach to the Workgroup based on the knowledge gained from the previous tasks. In consultation with the Workgroup, the Contractor shall identify a BWWW testing approach that can be employed for linehaul, short-line, and passenger trains.

Next, based on the data and activity patterns characterized by Tasks 2 and 3, the Contractor shall develop representative BWWW testing cycles for typical train types in California. Each BWWW testing cycle shall reflect the real-world operation characteristics of the corresponding train type, including travel duration, acceleration and deceleration profiles, stops, braking events and durations, brake pad and wheel temperature profiles, and environmental factors. For each train type, multiple test cycles can be developed if they are designed to represent portions of real-world activity patterns which can be characterized by average cycle speed, engine horsepower, or else.

Deliverable: BWWW testing cycles for each California representative train type.

**Task 4.** Develop a BWWW PM Emission Sampling System and a Test Plan

**Task 4a.** Develop a BWWW PM Emission Sampling System

The Contractor shall develop an emission sampling system according to the testing approach identified under Task 3c to measure train BW PM and WW PM emissions separately. The Contractor shall provide detailed information to the Workgroup about the sampling system design, including PM mass and PN sampling device choices, instrumentation setups, and data collection. This sampling system shall measure real-time BW and WW PM2.5 and PM10 mass, real-time BW and WW PN by size, BW and WW PM2.5 and PM10 gravimetric filter samples, and real-time gaseous emissions. The Contractor shall report PM and PN sample collection efficiencies at various train operating conditions for each test. The sampling system shall be suitable or easily adjustable for selected test subjects. The sampling system shall be able to measure both locomotive and railcar BWWW PM emissions.

Deliverable: A sampling system for measuring train BWWW PM emissions separately.

**Task 4b.** Conduct Pilot Tests

The Contractor shall perform pilot tests with the proposed sampling system, the developed BWWW testing cycle, and sample analysis protocols. The Contractor shall develop a pilot test plan and consult with the Workgroup before conducting plan tests. The Contractor shall present the Workgroup with the pilot test results and demonstrate the feasibility of a full-scale BWWW test along with the developed test cycles, the proposed BWWW PM sampling method, and the sample analysis plan. The Contractor shall adjust and modify test cycles and the proposed sampling method if the Workgroup requests.

Deliverable: Pilot test results.

**Task 4c.** Develop A Chemical Analysis Plan for PM Samples

Brake-wear, wheel/rail-wear, and background PMs are different in terms of chemical properties and compositions, and size distributions. The Contractor shall develop a chemical analysis plan for analyzing the collected gravimetric PM samples. The Contractor shall plan to perform a suite of chemical analyses, including elements, organic carbon and elemental carbon (OC/EC), metals, polycyclic aromatic hydrocarbons (PAHs), oxidative potentials, reactive oxygen species (ROS), dithiothreitol (DTT), total hexavalent chromium (Cr(VI)), etc. The Contractor shall follow standard analysis protocols and operating procedures for the PM analysis. The Contractor shall ensure the QA/QC of proposed testing protocols and operating procedures.

Deliverable: A sample analysis plan includes testing protocols and procedures.

**Task 4d.** Develop a Full Test Plan

The Contractor shall develop a full test plan for California's prevalent train types (including at least one line haul, short-line, and passenger trains), the testing cycles (Task 3c), and the sampling system (Task 4a). Each test subject should be tested for a minimum of three corresponding BWWW testing cycles. The Contractor shall also periodically check up on all the instrumentations to ensure the quality of the sampling. The Contractor shall demonstrate if each PM sample will provide sufficient mass for chemical analyses outlined in Task 4c.

Deliverable: A full test plan.

**Task 5.** Conduct Train BWWW Emission Measurements

The Contractor shall instrument all the test articles with sampling analyzers and conduct emissions measurement along with the test plan developed under Task 4d. For each test article instrumented, the Contractor shall collect information such as BWWW test cycle used, train type, brake and wheel material and type, train weight, vocation, railcar type, cargo type and weight, engine make, size, model and model year, and typical hours of use.

The Contractor shall perform each measurement for triplicate valid samples.

Deliverable: Raw data collected, including detailed information on units of measurement and conditions at detailed resolution.

**Task 6.** Analyze Emission Data and Develop EFs

**Task 6a.** Characterize BWWW Emissions by Train Type

The Contractor shall analyze and characterize BWWW emissions, including real-time PM mass, PN and particle size distribution, and gaseous emissions and gravimetric PM samples, under different train types and test conditions collected from Task 5. The Contractor shall report each test result of emissions as a function of train operation events and corresponding train speed, type, and cargo weight. The Contractor shall also evaluate the BWWW PM collection efficiency for each test and the background contamination percentage.

Deliverable: A report including table and graphs profiling BWWW PM emissions, including particle concentration, mass, and size distributions.

**Task 6b.** Analyze PM Compositions

The Contractor shall conduct chemical analysis as planned in Task 4, including performing a suite of chemical analyses including elements, OC/EC, metals, PAHs, oxidative potentials, ROS, DTT, and total Cr(VI) for collected gravimetric PM samples from Task 5. The Contractor shall use this information to estimate the mass percentage of major BW and WW PM2.5 and PM10 components. If it is believed that the PM samples are mixtures of brake-wear, wheel/rail-wear, and background dust, the Contractor shall conduct a source apportionment analysis to quantify the mass from each PM source.

Deliverable: A chemical analysis report.

**Task 6c.** Develop BWWW PM EFs

The Contractor shall develop the train BWWW PM EFs based on results from Task 6a and 6b. The Contractor shall characterize BWWW PM and PN emissions in grams or number of particles per miles traveled and locomotive engine horsepower used, respectively, for each train speed, train weight, train type, railroad conditions, and brake friction material type. The Contractor shall characterize average EFs by train speed either in equal intervals or any proposed speed bins by the Workgroup.

Deliverable: Corrected and adjusted BWWW PM EFs.

**Task 6d.** Develop BWWW EF Simulation Tool

The Contractor shall develop a computer simulation tool to estimate BWWW PM EFs by interpolating or extrapolating the results characterized in Task 6. Not all emissions encompassing train models, train cargo weights, train speed, brake, wheel, and rail materials, and travel routes will be measured or tested. Therefore, the Contractor shall construct a numerical tool to estimate BWWW PM EFs that will be applicable across different train types.

Deliverable: A computer simulation tool, either in a spreadsheet or database, to estimate BWWW PM EFs that is applicable for different train types.

**Task 7.** Evaluate Potential Health Risks to Near-Railroad Communities

The Contractor shall evaluate the potential health risks of BWWW PM emissions introduced to near-railroad communities based on the chemical analysis performed under Task 6b. The Contractor shall estimate the relative exposure level of the near-railroad communities considering the acquired BWWW EFs, the distance between the communities and the railroads, train types, and the corresponding EFs. The Contractor shall use tools, such as exposure models, to show the estimated exposure levels and potential health risks for the impacted communities.

Deliverable: A report discussing exposure level and any potential health risks to near-railroad communities from train BWWW PM emissions.

**Task 8.** Evaluate Study Limitations, Assess Current Programs, and Suggest Future Steps

The Contractor shall identify uncertainties and limitations of sampling system design, testing cycle development, emission measurements, data collection procedures, PM and PN characterization, and discuss their potential impacts on the profiled PM emissions at Tasks 3, 4, 5, 6, and 7. The Contractor shall also discuss further enhancement for measuring and characterizing non-exhaust PM emissions from trains. The Contractor shall assess opportunities to reduce PM emissions using regenerative braking technology and other advance technologies for trains.

The Contractor shall consult with EJ expert(s), or through other methods, to identify and understand potential community concerns of train BWWW PM emissions and exposure. The Contractor shall examine existing programs and policies and identify potentials and limitations to address the community concerns that can be considered for CARB's future policy considerations.

Deliverable: A report discussing the limitations of this research, the next steps, and potential BWWW reduction technologies. A summary of community concerns, assessment of current programs and policies, and future suggestions.

**Task 9.** Final Report and Seminar

The Contractor will provide Interim Reports, Final Report, a Public Research Seminar, and a Public Outreach Document. Upon completion of each task, the Contractor shall deliver an interim report and discuss with CARB staff the next deliverable tasks. The Contractor shall deliver a final report containing information from interim reports. As part of the final report, the Contractor shall include a Public Outreach Document, which will be widely used to communicate with the public. The Public Outreach Document shall include the key research findings from the study on one page with clear and direct terms. All reports shall be delivered using CARB standard templates. The Contractor shall also

prepare and deliver a research seminar to display the major findings from this study to the public.

## IV. DELIVERABLES

The project proposal must include but not be limited to the following deliverables:

**At Pre-Proposal Stage**

- Provide a cultural competency statement in the pre-proposal.
- Provide a community engagement plan in the pre-proposal.

**At the Beginning of the Contract**

- All researchers must undergo cultural competency training (examples include implicit bias training, racial equity training, etc.). Trainings should be completed or scheduled within 30 days of contract execution.
- Work with CARB staff at the beginning of the project to create a 1-page plain-language public outreach deliverable that describes the project's goals, process, and planned deliverables (available in multiple languages, template will be provided).

**During the Active Contract Period**

- Quarterly Progress Reports and conference calls. The progress reports will include plain-language summaries that can be posted publicly. A progress report template will be provided.
- Consultation calls with CARB and key stakeholders.

**Prior to Contract Close**

- All data, analyses, and analytical tools generated through the course of this project.
- Produce plain-language fact sheets, including suggestions for preventative actions (if such information is available), and these will be translated into Spanish.
- Draft final report (DFR).
- Include a plain language summary in the DFR.

- Include an equity implications section in the DFR.
- Work with CARB to create plain-language outreach deliverables for the public summarizing results and impact of the project (available in multiple languages).
- Final Report (ADA compliant) and virtual or in-person seminar.
- Peer-reviewed publications should be publicly available (please budget for this expense; submission-ready publications shall be reviewed by CARB staff).
- Additional deliverables to be determined in consultation with CARB staff.

## V. TIMELINE

It is anticipated that this project will be completed in 36 months from the start date. The cost shall not exceed $900,000.

**ITEM NO.: III.1**
**DATE: September 6, 2023**
**PROPOSAL NO.: 2873-307**

## DISCUSSION OF A RESEARCH PROPOSAL

| | |
|---|---|
| **TITLE:** | Improvement of the Toxic-Metal Aerosol Real-Time Analysis (TARTA) Instrument for Field Deployment |
| **PRIME CONTRACTOR:** | San Diego State University |
| **SUBCONTRACTOR:** | University of California, Davis |
| **PRINCIPAL INVESTIGATOR:** | Hanyang Li, Ph.D. |
| **CONTRACT TYPE:** | Interagency Agreement |
| **TOTAL AMOUNT:** | $150,000 |
| **CONTRACT TERM:** | 36 Months |

For further information, please contact Dr. Toshihiro Kuwayama at (279) 842-9873.

## I. SUMMARY

Toxic metals in ambient aerosols continue to be a concern for environmental justice (EJ) communities and communities near industry sources and traffic. This research aims to facilitate the refinement and deployment of the Toxic-metal Aerosol Real-Time Analysis (TARTA) instrument developed by University of California, Davis (UCD) under the previous CARB contract 17RD022. This new project will leverage the previous work to establish TARTA as a user-friendly tool for research, air monitoring, and citizen science applications.

Currently, TARTA relies on two expensive and proprietary software packages (IGOR and MATLAB) running on a high-end laptop for data acquisition and processing. The current prototype has internal consumable parts which require extensive setup in a well-equipped lab to provide reliable operation.

The proposed project would enable the Contractor to create a non-proprietary software that runs on a small single-board computer integrated into the instrument and produce an easy-to-replace nozzle/optics cartridge that removes the need for the complex lab setup.

This development project also includes the production of five of the newly designed TARTA, which will be provided to CARB at the end of the contract. These five instruments will be used to complement the objectives in proposed and ongoing studies with CARB involvement (e.g., toxic metal neighborhood screening, investigation of particulate matter (PM) in EJ neighborhoods and communities, toxic metals inventories, model verification, and complaint investigation). These instruments will be available for use by interested CARB stakeholders or loaned to community groups.

## II. TECHNICAL SUMMARY

In this project, the Contractor will write open-source software that will run on a Small Computing Device (SCD), which will be integrated into the TARTA-2 instrument. The software will be Linux based and use open-source operating system code and spectrum identification code supplied by the spectrometer manufacturer. The Contractor will develop a Graphic User Interface, which will have an easy-to-use mode and a mode for advanced users. These modifications will reduce the instrument's overhead cost significantly and enable the instrument to be operated from a single point.

The Contractor will write an operation manual with an easy-to-understand operations guide and a complete suite of technical operations and internal functions of the instrument for the advanced user.

The Contractor will have the Subcontractor (UCD) produce injection-molded pre-aligned particle trap/plasma cell units that will allow the gap in the plasma arc to be preset and eliminate the time-consuming setup in a lab environment when the electrodes need to be replaced.

The Contractor will repackage the instrument into a smaller, lighter case. The initial instrument was built on a heavy one-inch-thick laser alignment table which required a

large case and was quite heavy. The new injection molded pre-aligned plasma/optics heads will eliminate the need for the alignment table and the large case. These improvements will improve the usability and serviceability of the instrument while also making it considerably more portable.

The SCD integration and the open-source software will simplify the spectrum recognition and data collection system, while the injection molded particle trap/plasma cell units will significantly reduce the maintenance requirements while reducing the size and weight of the instrument. The operation manual will be written to be accessible to both users with a non-scientific background and users who need a more advanced understanding of the operation. These improvements will make the TARTA-2 a field-deployable instrument that can be readily used by CARB staff and other end-users with minimal training.

**Objective**

The main objective of this new contract is to refine the instrument created in the initial CARB contract 17RD022. This work will take that proven successful development instrument for measuring toxic metals in ambient aerosols to be transformed from a laboratory test platform into a fully field-deployable and serviceable instrument. This contract specifies that the Contractor will produce five of the newly redesigned instruments (TARTA-2) to be given to Research Division (RD) at the end of the contract.

## III. STAFF COMMENTS

The Contractor, Dr. Hanyang Li, was the lead developer of TARTA while a Post-Doctoral Fellow in Dr. Anthony Wexler's group at UCD. Dr. Li will oversee a Graduate Student Researcher (TBA) in this project to work on device design, testing, characterization, field deployment, and software development.

The Contractor has secured the use of the injection molding and engineering support of UCD as Subcontractor. The Subcontractor will be Dr. Wexler and Chris Wallis (an engineer in the Air Quality Research Center) at UCD. Dr. Wexler will provide guidance

and technical support as needed. Chris Wallis will provide assistance for technical, software, and hardware problems. All investigators will work on report writing.

The Contractor, Dr. Li, has also retained, at no cost, an industry professional. Dr. Fred Brechtel, Brechtel's Chief Executive Officer and Owner, will advise the Contractor on instrument optimization and manufacturing based on his expertise in developing airborne PM measurement technologies. The association will have a direct tie to the TARTA becoming an instrument that will be available at retail to any prospective user.

Staff notes this group has the experience and resources to bring the TARTA instrument to a field-ready state.

## IV STAFF RECOMMENDATION

Staff recommends the Research Screening Committee recommend that CARB accept this proposal for $150,000.

**ITEM NO.: IV.1**
**DATE: September 6, 2023**
**CONTRACT NO.: 22RD036**

## DISCUSSION OF A PROPOSED CONTRACT AUGMENTATION

| | |
|---|---|
| **TITLE:** | Quantifying and Identifying the Potential Causes of Nitrous Oxide Emissions in California Soils under Fumigation (Phase 2) |
| **PRIME CONTRACTOR:** | University of California, Davis |
| **SUBCONTRACTOR:** | University of Wisconsin-Madison |
| **PRINCIPAL INVESTIGATOR:** | Jorge L. Mazza Rodrigues, Ph.D. |
| **CONTRACT TYPE:** | Interagency Agreement |
| **TOTAL AMOUNT:** | $400,000 |
| **CONTRACT TERM:** | 24 Months |

For further information, please contact Dr. Dongmin Luo at (916) 277-0834.

## I. SUMMARY

Nitrous oxide ($N_2O$) is a potent greenhouse gas (GHG), contributing 13 $MMTCO_2e$, or 3.5 percent of California's GHG inventory. Emissions from agricultural soils represent the largest source (45 percent) of $N_2O$ in California, driven primarily by soil microbial activities. Fluxes of $N_2O$ from agricultural soils are related to the soil nitrogen (N) content, but are extremely variable both spatially and temporally, reflecting variations of soil conditions such as soil organic matter content, water content, and temperature that affect microbial activities. CARB, in coordination with other state agencies, has conducted multiple research projects over the past decade characterizing $N_2O$ emissions from California agricultural soils. However, impacts of pesticide application, such as fumigation, on $N_2O$ emissions have received little attention. The project will perform field and laboratory experiments to investigate $N_2O$ emissions in fumigated and non-fumigated soils and develop modified emission factors integrating fumigation effects on $N_2O$ emissions. Results of this project will address a key knowledge gap on the impact of fumigant applications on $N_2O$ emissions, inform CARB's $N_2O$ inventory, and support the California

Department of Pesticide Regulation's (CDPR) decision making on management of fumigant use in California croplands.

## II. TECHNICAL SUMMARY

### Objective

The goal of this project is to evaluate impacts of fumigant application on $N_2O$ emissions from agricultural soils in California. Specific objectives of the project are to: 1) determine $N_2O$ emission rates from major cropping systems in California that receive both fumigant and fertilizer applications under different management practices; 2) develop modified emission factors of $N_2O$ emissions including fumigation effects; 3) identify key environmental and microbial controls on $N_2O$ emissions from fumigated crops to inform mitigation; and 4) upscale observed fumigation impacts statewide to evaluate overall impacts of fumigant use in agricultural soils on $N_2O$ emissions in California.

### Background

Emissions of $N_2O$ from agricultural soils are part of the natural N cycling process. Nitrogen-containing chemicals in soil can be converted into $N_2O$ through biogeochemical processes of nitrification and denitrification mediated by soil microorganisms. Agricultural lands are the major source of soil $N_2O$ in California as they receive N fertilizers regularly for enhanced crop yields. Concerns have been raised recently by stakeholders on pesticides' impacts on the emissions of $N_2O$ from agricultural soils. Limited experiments on short-term monitoring have shown that some pesticides, in particular fumigants, could increase soil $N_2O$ emissions substantially, but the results are inconsistent, depending on pesticide type and application rates as well as crop management practices. This project will measure $N_2O$ fluxes from California agricultural fields over an extended time to investigate fumigants' impacts on $N_2O$ emissions in real world conditions and assess emission factors in cropping systems that receive both fumigants and fertilizer applications. The study will provide much needed evidence whether our current $N_2O$ inventory should include pesticides' impacts.

**Proposal Summary**

The current proposal is the Phase 2 study on pesticides' impacts on $N_2O$ emissions from agricultural soils, which is built upon an existing contract (the Phase 1 study). Phase 1 is supported by CARB's Industrial Strategies Division (ISD) and consists of four tasks (Tasks 1 to 4), with a focus on literature review and sampling preparation, including identifying cropping systems and fumigants to be studied, locating monitoring sites, and developing monitoring protocols. Phase 2 will focus on emission monitoring and data analysis, consisting of the following four tasks (Tasks 5 to 8).

**Task 5:** Measuring $N_2O$ fluxes from fumigated and non-fumigated soils.

Field monitoring of $N_2O$ emissions from the selected crops in Phase 1 will be conducted under prevailing management practices for one year following fumigant application, surrounding periods with expected $N_2O$ flux pulses from fertilizer application, irrigation, and precipitation.

**Task 6:** Determining $N_2O$ emission factors and potential mitigation strategies.

Emission factors of $N_2O$ from fumigated crops will be calculated and compared across different crops, fumigants, applications rates, etc. to identify key environmental controls on $N_2O$ emissions and inform mitigation options. In addition, laboratory experiments will be conducted to determine and relate soil denitrification rates in the field to microbial communities and function genes to further inform mitigation strategies.

**Task 7:** Upscaling observed fumigant impacts to statewide emissions.

The observed emission factors will be upscaled statewide, based on California-specific cropland and activity data, to evaluate overall impacts of fumigant use in agricultural soils on $N_2O$ emissions and determine if an updated $N_2O$ inventory incorporating fumigant impacts is necessary.

**Task 8:** Preparing progress and final reports.

Quarterly progress reports will be provided throughout the project duration. The final report and associated publications will be subject to stakeholders' review and approval.

## III. STAFF COMMENTS

The project was initiated in response to stakeholders' request. California Department of Food and Agriculture (CDFA) led a discussion with the University of California (UC), California State University professors, and the United States Department of Agriculture (USDA) researchers to explore the significance of fumigant use on $N_2O$ emissions in California and assess the research needs. CDFA, CDPR, and CARB are all in support of the research project and are involved in the process of developing the proposals. CARB's ISD supported the Phase 1 contract, which is attached to this Phase 2 proposal, with $200,000 with UC Davis (UCD) to perform a literature review, identify the crop systems and fumigants to be monitored based on California-specific activities, and develop monitoring protocols. The Phase 2 study would monitor $N_2O$ emissions in the field and produce real-world emission data that are necessary to address the stakeholders' concerns. The UCD team led by Dr. Jorge L. Mazza Rodrigues has strong expertise in the areas of soil biogeochemistry and soil microbiology, focusing, in particular, on carbon and nitrogen biogeochemical processes in soil, and the team members have performed research projects measuring $N_2O$ emissions from multiple cropping systems in California. The team also possesses the equipment/devices (both GC and LICOR Gas Analyzer) required for measuring soil emissions and hence the project is cost-effective.

## IV. STAFF RECOMMENDATION

Staff recommends the Research Screening Committee recommend that CARB accept this contract augmentation for $400,000.

**ITEM NO.: V.1**
**DATE: September 6, 2023**
**CONTRACT NO.: 20STC008**

## STAFF EVALUATION OF A DRAFT RESEARCH FINAL REPORT

| | |
|---|---|
| **TITLE:** | Post-COVID Transportation Scenarios: Evaluating the Impact of Policies |
| **PRIME CONTRACTOR:** | University of California, Davis |
| **PRINCIPAL INVESTIGATOR:** | Susan Handy, Ph.D. |
| **CONTRACT TYPE:** | Interagency Agreement |
| **BUDGET:** | $199,936 |
| **CONTRACT TERM:** | 30 Months |

For further information, please contact Dr. Melanie Zauscher at (279) 208-7951.

## I. SUMMARY

The COVID-19 pandemic caused changes in how people travel. Whether these changes will persist, return to pre-COVID trends, or move in other directions is uncertain, creating an unprecedented challenge for transportation planners. This project explores several possible scenarios for transportation after the COVID-19 pandemic and assesses possible policies to improve outcomes. The research team developed four post-COVID scenarios for California defined by assumptions for five key modalities: telecommuting, e-shopping, ride-hailing, public transit, and active travel. The research team used outputs from the State's travel demand model and implemented a post-processing approach to model these scenarios. The results show increases in trips and vehicle miles traveled (VMT) compared to the pre-COVID forecast across the first three scenarios but a small decrease for the fourth scenario, which assumes the strongest shift toward alternatives to driving. An equity analysis of the model results provides additional insights. A wide array of policies could help California to minimize the negative impacts while maximizing the positive impacts of post-COVID trends from the standpoint of both reducing greenhouse gas (GHG) emissions and enhancing transportation equity. The results of

this study will help inform CARB's ongoing implementation of Sustainable Communities Strategies through the Senate Bill (SB) 375 program.

## II. TECHNICAL SUMMARY

### Objective

The research objective of this project was to examine transportation and land use policies based on lessons learned from the COVID-19 pandemic that CARB and the State could institute to help meet California's air quality, climate, and equity goals.

### Background

The COVID-19 pandemic has had significant impacts on society and transportation in California, including:

- Reduced total VMT during shelter-in-place orders
- Shift to telecommuting for high-wage employees
- Reduced use of public transportation and pooling
- Lower prices of petroleum-based fuels
- Improved air quality, but not as much as expected
- Reduced GHG emissions

Although the short-term impacts listed above are significant, some of the blunt policy responses (e.g., shelter-in-place) that were necessary during the pandemic are not viable methods for reducing pollution and carbon emissions to meet California's long-term goals. The long-term impacts from the COVID-19 pandemic are very uncertain for a variety of reasons, including shifts away from commutes that were served by more sustainable modes of travel (i.e., transit and pooling), greater reliance on delivery of goods, and changes in land use preferences due to the pandemic that may also lead to changes in travel behavior. Lastly, the negative impacts of the pandemic were felt disproportionally in communities of color and lower income households. Although some trends have returned to "normal," some of the impacts of the COVID-19 pandemic will likely persist for a while.

**Project Summary**

The Contractor developed four future scenarios that aim to capture differing post-COVID travel possibilities: 1) COVID trends persist; 2) return to pre-COVID trends; (3) urbanism returns; and 4) urbanism bounces ahead. These scenarios are defined by assumptions about five key modalities: telecommuting, e-shopping, ride-hailing, public transit, and active travel. The assumptions are based on an extensive review of the literature on pre-COVID trends, during-COVID changes, and post-COVID forecasts for each of these modalities. Key assumptions for each scenario are as follows: 1) COVID trends persist assumes a reduction in short distance trips in both 2030 and 2050 for telecommuting, e-shopping, transit, and active travel; 2) return to pre-COVID trends assumes a reduction in short distance trips in both 2030 and 2050 for telecommuting, and no change from the business as usual (BAU) scenario in 2030 and 2050 for transit and active travel; 3) urbanism returns assumes a reduction in short distance trips in 2030 and 2050 for telecommuting and e-shopping, an increase in working transit trips in both 2030 and 2050, and substitution of auto trips for active travel in both 2030 and 2050; and 4) urbanism bounces ahead assumes a reduction in short distance trips in 2030 and 2050 for telecommuting and e-shopping, an increase in working transit trips in both 2030 and 2050, and substitution of auto trips for active travel in both 2030 and 2050, all at higher rates than the urbanism returns scenario.

To model these scenarios, the Contractor used outputs from the California Statewide Travel Demand Model (CSTDM) for 2030 and 2050. The BAU scenario uses the CSTDM baseline projections at the Traffic Analysis Zone (TAZ) level, which was developed before the COVID-19 pandemic. Each scenario was developed by applying a post-processing approach to the baseline that adjusted trips by mode and trip purpose to reflect the specific assumptions of the scenario with respect to the five modalities. The research team examined numbers of trips, VMT, and mode shares for each scenario to assess their implications for GHG emissions and other environmental impacts.

A key finding was that trips and VMT increase compared to the pre-COVID forecast across the first three scenarios, though results differ with respect to patterns of mode use

and trip purpose. The fourth scenario, which assumed the strongest shift toward alternatives to driving, results in a small decrease in VMT relative to the pre-COVID forecast.

The Contractor also analyzed the equity implications of each of the scenarios by comparing the travel outcomes of VMT, trip length, and mode share aggregated by three socioeconomic characteristics: neighborhood designation using equity priority area definitions at the TAZ level, and household income and household car ownership at the trip level. The study also examined regional travel patterns to understand the spatial distribution of transportation equity considerations. Although higher numbers of vehicle trips and VMT can reflect a positive outcome for some disadvantaged households (e.g. if the additional driving helps low-income workers reach higher paying jobs), this study assumed that more driving is generally a burden for disadvantaged households because: 1) driving imposes a financial burden on these households; 2) it may reflect poor accessibility to jobs and other activities by more affordable modes; and 3) the environmental impacts of driving are especially acute in disadvantaged communities.

Results from the scenario analysis show that disadvantaged groups would continue to face burdens under some model assumptions. While the model predicts that disadvantaged groups (by geography, income, and car ownership status) will drive less and for shorter cumulative distance than advantaged groups in all scenarios, their driving is highest in the scenario where COVID pandemic trends persist into the future, suggesting a high degree of burden compared to other scenarios.

The Contractor explored a variety of policies the State could consider to minimize the negative impacts while maximizing the positive impacts of post-COVID trends from the standpoint of both reducing GHG emissions and enhancing transportation equity. Potential policy mechanisms for achieving the ambitious VMT reduction goals set by the State include driver-targeted policies (i.e., road charges), employer-targeted policies (telework), land-use changes, transit investments (operational funding, address driver

shortages, streamline fare payment systems), further regulation of transportation network companies (TNC), and investments in bike and pedestrian infrastructure.

It is unclear which of the four scenarios the post-COVID future in California will most closely resemble. It is also possible that the future will reflect a combination of the scenarios – or will look very different than both the CSTDM and the assumptions in these scenarios suggest. Although these scenarios are hypothetical, the results provide useful insights into future travel patterns as well as a baseline against which to compare other possible post-COVID scenarios. The estimates of increases in VMT and total trips for three of the four scenarios is discouraging from the standpoint of meeting California's goals for emissions reductions, but the differences between scenarios point to the importance of state, regional, and local policy in the State's efforts.

## III. STAFF COMMENTS

At the beginning of this project, there was a change in the Principal Investigator from Dr. Austin Brown to Dr. Susan Handy.

The research team delivered the first DFR to CARB in March 2023, which was subsequently distributed for review to various staff within CARB, the Strategic Growth Council, the California Department of Transportation, and the California Energy Commission. CARB staff reviewers included representatives from The Sustainable Transportation and Communities Division, the Mobile Source Control Division, the Air Quality Planning and Science Division, and the Research Division.

Staff comments were generally positive and expressed interest in the policy recommendations provided. The research team has addressed staff comments and provided robust discussion in the final report in response to comments. CARB staff identified an issue with VMT calculations, which has subsequently been addressed and incorporated into the necessary figures. A second round of feedback on the DFR from CARB staff will be shared with the research team. Based on the deliverables provided to CARB to date, we are confident that the research team will fulfill the outstanding request for edits in a timely manner.

Some reviewers provided comments that fall beyond the scope of this project, such as expanding the CSTDM to include VMT from ride-hailing services and converting travel patterns to welfare measures.

## IV. STAFF RECOMMENDATION

Staff recommends the Research Screening Committee recommend that CARB accept this draft final report for $199,936.

**ITEM NO.: V.2**
**DATE: September 6, 2023**
**CONTRACT NO.: 20RD003**

## STAFF EVALUATION OF A DRAFT RESEARCH FINAL REPORT

| | |
|---|---|
| **TITLE:** | Airborne Flux Measurements of Volatile Organic Compounds and Oxides of Nitrogen in California |
| **PRIME CONTRACTOR:** | University of California, Berkeley |
| **PRINCIPAL INVESTIGATOR:** | Allen Goldstein, Ph.D. |
| **CONTRACT TYPE:** | Interagency Agreement |
| **BUDGET:** | $700,000 |
| **CONTRACT TERM:** | 36 Months |

For further information, please contact Dr. Toshihiro Kuwayama at (279) 842-9873

## I. SUMMARY

The primary objective of this project is to accurately quantify volatile organic compounds (VOC) and nitrogen oxide ($NO_X$) emissions in the San Joaquin Valley (SJV) and the South Coast Air Basin (SoCAB) by employing aircraft-based flux measurements. In June 2021, 16 research flights were conducted to map the emissions of $NO_X$ and a wide range of VOCs using state-of-the-science instrumentation for eddy covariance measurements. The measured emissions are then directly compared with the emission inventories provided by CARB. The results indicate that VOC and $NO_X$ inventories representing traffic emissions are more consistent with observations than those representing biogenic or VCP emissions. In the SJV, the observed fluxes reveal an underestimation of soil $NO_X$ fluxes by an order of magnitude, an underestimation of dairy and citrus processing VOC fluxes, and an overestimation of biogenic isoprene fluxes by the inventories. In the SoCAB, the observations suggest that the inventory overestimates $NO_X$ emissions near the coast while underestimating them inland. The underestimation was likely due to increased warehouses in recent years and the associated delivery truck activities that were not incorporated in the CARB 2020 emission inventory. Furthermore, the inventory underestimates biogenic VOC emissions for mono- and sesquiterpenes by a factor of 5.

Additionally, the results highlight that biogenic terpenoid emissions contribute, on average, 60 percent to ozone and secondary organic aerosol formation in summertime Los Angeles. It is noted that this contribution significantly increases with temperature and that these emissions are largely missing in the current inventories. Overall, the findings from this project will carve a path that improves the emissions inventories used by CARB and subsequently refine the predictive capabilities of photochemical modeling used to develop the State Implementation Plans (SIP).

## II. TECHNICAL SUMMARY

### Objective

The objective of this project is to directly measure VOC and $NO_X$ fluxes by airborne eddy covariance across spatial scales that are pertinent to air quality models and use this information to assess and improve emission inventories in California.

### Background

Under the Federal Clean Air Act, CARB is responsible for developing the SIPs to achieve health-based air quality standards. While California has significantly reduced ambient ozone levels over the past few decades, many regions across the state still exceed the National Ambient Air Quality Standards (NAAQS) for ozone. The recent plateauing of average ambient ozone levels in California poses additional challenges for reducing ozone design values and improving air quality. This plateauing phenomenon may be attributed to a combination of changing ozone precursors sources and atmospheric sensitivities to ozone formation pathways. Therefore, an improved understanding of the emissions of these precursors, namely VOCs and $NO_X$, is crucial for the improvement of the photochemical models used to develop SIPs.

Photochemical modeling serves as a crucial tool in the development of SIPs. These models rely on emission inventories of VOCs and $NO_X$ as inputs. The spatial and temporal distribution and the magnitude of VOC and $NO_X$ emissions significantly impact modeling results. However, these emission inventories are associated with high levels of uncertainty, and there is limited validation of their accuracy based on measurement data. To enhance the performance of these models, reducing the uncertainties in VOC and

$NO_X$ emission inventories through direct measurements is imperative. This project aims to validate and improve CARB's emission inventories by directly measuring VOC and $NO_X$ fluxes in the SJV and the SoCAB. The project seeks to provide scientific insights to inform SIPs that reduce ozone air pollution by comparing the observed flux with current inventories.

**Project Summary**

The DFR summarizes the results for the following major tasks.

***Task 1****:* Field campaign planning

The flight routes were carefully planned, taking into account multiple factors such as the existing emission inventories, literature, TROPOMI $NO_2$ data, and discussions with CARB staff. Additionally, considerations were made to adhere to methodological requirements for airborne flux measurements.

***Task 2****:* Preparing for field campaign

This preparation included pre-installation instrument characterization, configuration, calibration, and comprehensive safety reviews. Additionally, the instruments were seamlessly integrated into the aircraft, followed by rigorous ground systems tests to verify their functionality. To assess the readiness of the equipment, a 2-hour test flight was conducted from the NPS Twin Otter facility in Marina, CA, before the actual deployment phase.

***Task 3:*** Airborne flux measurements

The field campaign encompassed a total of 80 flight hours, divided into 16 flights, with 9 flights conducted in the SoCAB and 7 flights in the SJV. To ensure consistency and comparability, the same flight tracks were repeated during each flight. The selection of flight days was based on careful consideration of the weather forecast to ensure cloud-free conditions and a suitable range of temperature variations between flights. Furthermore, both weekends and weekdays were included to capture potential differences in emissions and atmospheric conditions during different time periods.

**Task 4:** Analyzing airborne flux data

Airborne eddy covariance fluxes were calculated using wavelet transformation, resulting in highly spatially resolved airborne fluxes. Significant fluxes were observed for more than 130 VOCs. Mapping and aligning the flux footprints with inventory grid cells enabled spatial, temperature-based, and weekday-based comparisons. Additionally, land-cover data was incorporated into the analysis to perform source attribution and quantification using footprint disaggregation and multivariate linear regression.

## III. STAFF COMMENTS

A previous version of the report underwent a thorough review by staff from CARB's Research Division, CARB's Air Quality Planning and Science Division, and the South Coast Air Quality Management District. The current version incorporates the comments and feedback. The report provides an accurate account of the completed work, implications of the results, and identifies areas for future research.

The project achieved its objectives, generating unprecedented flux data for $NO_X$ and a wide range of VOCs. The comparisons between the observed fluxes and the inventory data establish a robust scientific path for improving both the emissions inventories and the photochemical modeling used for SIP development. The acquired data and findings have raised awareness regarding emissions and have prompted potential measures to enhance comprehension of various sources, such as soil $NO_X$ emissions and emissions from dairy-related activities. Moreover, the Contractors leveraged additional resources and conducted more flight measurements than required by the contract, demonstrating their dedication and exceeding expectations.

In addition, the Contractors have made significant contributions to the scientific community by submitting five manuscripts to prestigious journals, including Science, Environmental Science & Technology, and Atmospheric Chemistry and Physics. This achievement highlights the success and high-quality outcomes of the project. Below is a list of the manuscripts. The information presented in these manuscripts are reflective of the data that was collected during this project.

Clara M. Nussbaumer, Bryan K. Place, Qindan Zhu, Eva Y. Pfannerstill, Paul Wooldridge, Benjamin C. Schulze, Caleb Arata, Ryan Ward, Anthony Bucholtz, John H. Seinfeld, Allen H. Goldstein, and Ronald C. Cohen. Measurement report: Airborne measurements of $NO_X$ fluxes over Los Angeles during the RECAP-CA 2021 campaign, Atmospheric Chemistry and Physics, under review. https://doi.org/10.5194/egusphere-2023-601.

Eva Y. Pfannerstill, Caleb Arata, Qindan Zhu, Benjamin C. Schulze, Roy Woods, Colin Harkins, Rebecca H. Schwantes, John H. Seinfeld, Anthony Bucholtz, Ronald C. Cohen, and Allen H. Goldstein. Mismatches between inventories and spatially resolved airborne flux measurements of volatile organic compounds in Los Angeles. Environmental Science & Technology, under review.

Eva Y. Pfannerstill, Caleb Arata, Qindan Zhu, Benjamin C. Schulze, Roy Woods, Colin Harkins, Rebecca H. Schwantes, John H. Seinfeld, Anthony Bucholtz, Ronald C. Cohen, Allen H. Goldstein. Volatile organic compound fluxes in the San Joaquin Valley – spatial distribution, source attribution, and inventory comparison. Atmospheric Chemistry and Physics, under review. https://doi.org/10.5194/egusphere-2023-723.

Eva Y. Pfannerstill, Caleb Arata, Qindan Zhu, Benjamin C. Schulze, Ryan Ward, Roy Woods, Colin Harkins, Rebecca H. Schwantes, John H. Seinfeld, Anthony Bucholtz, Ronald C. Cohen, and Allen H. Goldstein. Temperature-dependent emissions dominate aerosol and ozone formation in Los Angeles. Science, under review.

Qindan Zhu, Bryan Place, Eva Y. Pfannerstill, Sha Tong, Huanxin Jessie Zhang, Jun Wang, Clara M. Nussbaumer, Paul Wooldridge, Benjamin C. Schulze, Caleb Arata, Anthony Bucholtz, John H. Seinfeld, Allen H. Goldstein, Ronald C. Cohen. Direct observations of NOx emissions over the San Joaquin Valley using airborne flux measurements during RECAP-CA 2021 field campaign. Atmospheric Chemistry and Physics, under review. https://acp.copernicus.org/preprints/acp-2023-3/.

## IV. STAFF RECOMMENDATIONS

Staff recommends the Research Screening Committee recommend that CARB accept this draft final report for $700,000.

**ITEM NO.: V.3**
**DATE: September 6, 2023**
**CONTRACT NO.: 20RD008**

## STAFF EVALUATION OF A DRAFT RESEARCH FINAL REPORT

| | |
|---|---|
| **TITLE:** | Decision Drivers to Facilitate Lower-Polluting Product Choices by Consumers |
| **CONTRACTOR:** | University of California, Los Angeles |
| **PRINCIPAL INVESTIGATOR:** | Magali Delmas, Ph.D. |
| **CONTRACT TYPE:** | Interagency Agreement |
| **BUDGET:** | $200,000 |
| **CONTRACT TERM:** | 36 months |

For further information, please contact Dr. Sarah Pittiglio at (279) 842-9114.

## I. SUMMARY

Behavioral interventions that encourage the voluntary adoption of lower-polluting products and choices are an important tool for CARB to reach its emissions goals. This contract aims to improve CARB's ability to encourage adoption through a systematic review of the literature on successful behavioral interventions related to reducing polluting behaviors and the design of a real-world test of a messaging strategy encouraging a desirable behavior (attending a CARB webinar). The systematic review found that highlighting the private benefits of lower-polluting goods, rather than solely emphasizing the environmental benefits, may be a useful approach for encouraging behavior change. The research team also designed a test of wording encouraging the public to attend CARB webinars. The strategies highlighted in the systematic review should be incorporated into CARB programs to test their efficacy.

## II. TECHNICAL SUMMARY

### Objective

This contract aims to provide a systematic review of the literature on successful behavioral interventions in a lower-polluting context and to design a test of a strategy in a real-world context.

### Background

Consumer choices are a major contributor to emissions. While CARB has authority to regulate some actions, voluntary actions are necessary to help CARB achieve its goals. Behavioral interventions can be an effective strategy for encouraging lower-polluting behaviors without the use of regulation or financial incentives. This systematic review presents the successful strategies from the research literature from the past decade, highlighting the promotion of private benefits of low-polluting goods.

### Project Summary

The systematic review provides an overview of the literature on successful behavioral interventions in a lower-polluting context from 2012 to 2023, for a total of 71 included articles. The articles were coded for variables including their intervention strategy and the outcome of the intervention. The researchers used the Green Bundle Framework to help categorize the strategies, which are: quality, social, financial, health, and emotion, as well as the non-Green Bundle category of environmental-only. The review cannot make recommendations regarding which strategies are most effective in different circumstances or which strategies are likely to be effective, however, it highlights quality, social, and financial as having the largest body of supportive evidence. The researchers find there are few studies showing successful interventions using the environmental-only approach, and that these studies tend to be of lower quality. The policy recommendation of the systematic review is to emphasize the private benefits of lower-polluting products and choices, perhaps in addition to the environmental benefits.

The researchers considered strategies to increase attendance at CARB webinars and tested these strategies using an online sample of participants stating their hypothetical likelihood of attending a webinar. In the first experiment, the researchers varied the

phrasing of the hypothetical invitation, including a message using both fear of missing out and human interaction: “Don’t miss your chance to interact with the researchers and ask your questions.” The results did not show a difference between the messages tested. The researchers ran another set of tests emphasizing egoistic and altruistic motivations: “We need your insights, inputs, and ideas.” The results for the second set of experiments show a significant increase in the hypothetical likelihood of attending the webinar. The researchers prepared a pre-analysis plan for testing messages sent to a CARB listserv for research seminars.

## III. STAFF COMMENTS

Staff have reviewed the DFR and worked with the researchers through multiple iterations of the DFR. Comments and review came from staff in CARB’s Air Quality, Planning and Science Division, Mobile Source Control Division, and the Research Division (RD), as well as CalRecycle. The comments primarily focused on clarification, interpretation of results, and applications to CARB. The researchers addressed the majority of the comments and provided additional explanations through emails. There are remaining issues that the researchers do not believe need to be addressed.

The remaining issues include uncertainty about how to interpret the rationale of the inclusion criteria, in which the researchers chose to exclude insignificant results if they appear in a study that also has significant results. The inclusion criteria state: “If an article reports multiple interventions, only significant differences will be included, and the effect will be coded as significant. If an article reports only non-significant findings, the effect will be coded as non-significant.” Staff asked for a brief description of how to interpret R squared as a measure of effect size reported in the systematic review spreadsheet, but this was not provided by the researchers. Staff asked for the rationale for the sample size in Experiment 2, but this was not provided. Staff asked that a note be included to explain the difference in findings between the present review and Rau et al. (2022), another systematic review covering nearly the same topic which finds “The results show that most interventions only have small positive effects or none at all.” The researchers believe that an explanation of the differences between the reviews is unwarranted. Despite these

remaining differences, the DFR is a valuable resource to CARB that highlights many different successful interventions that CARB could use as a model for its own tests of behavioral interventions.

## IV. STAFF RECOMMENDATIONS

Staff recommends the Research Screening Committee recommend that CARB accept this draft final report for $200,000.

**ITEM NO.: V.4**
**DATE: September 6, 2023**
**CONTRACT NO.: 19RD009**

## STAFF EVALUATION OF A DRAFT RESEARCH FINAL REPORT

| | |
|---|---|
| **TITLE:** | Strategies for Incentivizing High-Occupancy, Zero-Emission, New Mobility Options |
| **CONTRACTOR:** | University of California, Berkeley |
| **PRINCIPAL INVESTIGATOR:** | Paul Waddell, Ph.D. |
| **CONTRACT TYPE:** | Interagency Agreement |
| **BUDGET:** | $700,000 |
| **CONTRACT TERM:** | 36 months |

For further information, please contact Dr. Sarah Pittiglio at (279) 842-9114.

## I. SUMMARY

Single occupancy vehicle miles traveled (VMT) are a significant source of greenhouse gas (GHG) emissions and increasing occupancy to reduce VMT per person is an important climate mitigation strategy. Various alternative transportation methods and high-occupancy strategies exist including transit, micromobility, road pricing, park and ride and van-pooling, however, various barriers to their widespread adoption still exist. The objective of this project is to explore a variety of research methods to probe what those barriers are and to conceptualize possible strategies to incentivize widespread adoption of high-occupancy travel modes. The research team used a literature review, focus group interviews, expert interviews, a statewide survey, analysis of micromobility temporal and location data, and a land-use and activity model to better understand the impacts of different strategies on adoption of high-occupancy modes. The results showed that significant barriers still exist related to equity, built environment and land-use. The pandemic also led to changes in transportation and housing patterns which, although attenuated, have negatively impacted the uptake of high-occupancy travel modes. The modeling of policy scenarios highlighted the benefits of combining multiple policies, however, fewer benefits of various policies, individually or in combination, are associated

with low-income populations. The results of this project will continue to inform strategies adopted as part of SB 375, and results will also be highlighted in the next SB 150 report. The policy strategies explored during this study can be used to guide future decisions made by Metropolitan Planning Organizations (MPO) in order to meet VMT reduction targets. The barriers to equitable access to clean and affordable transportation must be a priority for MPOs based on the results of this report.

## II. TECHNICAL SUMMARY

### Objective

This research project seeks to identify barriers and examine possible strategies for incentivizing growth and greater uptake of high-occupancy, zero-emission shared mobility and active transportation options in California. In particular, the research will seek to understand the impacts of various strategies on vulnerable populations. The results of this project will inform future policy interventions impacting travel mode choice with the aim of reducing GHG emissions from the transportation sector while also prioritizing equitable outcomes.

### Background

Various recent developments in transportation options including ridesharing, TNC, carsharing, micromobility, active transportation, automated vehicles (AV) and multi-modal mobility have significantly changed the landscape of transportation choice, particularly in urban areas. The COVID-19 pandemic also led to significant adoption of telework for specific labor segments and further shifted transportation mode choices and patterns. As the pandemic has progressed, a “new normal” has settled into place with some of those changes in transportation patterns remaining. The transportation sector accounts for 40 percent of all GHG emissions in CA and individual passenger on-road travel is a significant contributor. As part of CARB’s Scoping Plan, a reduction in VMT per capita of 25 percent below 2019 levels by 2030, and 30 percent below 2019 levels by 2045 is needed to meet Assembly Bill (AB) 32 goals. Other statutes, like SB 375 seek to reduce demand for fossil transportation fuels, GHGs and to improve air quality in response to Board direction and Environmental Justice Advisory Committee recommendations. There

is a need to better understand the potential impact that policy strategies incentivizing the uptake of zero-emission, high-occupancy travel modes could have in furthering the goals mandated by AB 32 and SB 375, and others. This project responds to this need by exploring various research methods to identify barriers to adoption of high-occupancy, zero-emission travel modes, and exploring the impact of potential policy interventions.

**Project Summary**

The research team explored six different research methods to fulfill the project objectives.

**1. Literature Review**

The research team used keywords representing high-occupancy, zero-emission travel modes across various journals, scholarly databases and gray literature in order to provide background information and to inform the other research tools used in this project. Findings from studies were aggregated and key takeaways summarized in tables to provide an overview of current trends.

**2. Expert Interviews**

The research team interviewed fourteen experts from various types of organizations that included Clean Mobility Options grantees, community-based organizations, private companies, public transit agencies, travel demand modelers and others. The results of these interviews covered various topics such as the impacts of the pandemic, typical barriers to different strategies such as pooled rides, active transportation, and electrification, and finally, various issues and barriers related to social equity.

**3. Focus Groups**

Two focus group interviews were conducted, one with nine participants from Southern California and one with ten participants from Northern California. The focus group interview results helped the researchers understand people's travel patterns, housing choices and pandemic impacts. In addition, the interviews helped refine the survey method.

**4. Activity Analysis**

The researchers analyzed open-source General Bikeshare Feed Specification data and the American Community Survey data to understand issues of access to shared micromobility resources and derive access and equity related metrics. The approach consisted of creating metrics representing access based on vehicle dwell time and availability per household. Demographics of individual users was not available, so the team used the average demographics per census tract where vehicles were being used. Correlations were derived between demographics and accessibility based on the average census tract information and the metrics developed during the analysis.

**5. Survey**

A general population survey deployed in five major metropolitan regions (San Francisco Bay Area, Los Angeles, Sacramento, San Diego, and the Central Valley) with 2,354 responses. The survey collected demographic information, travel mode and travel pattern information, and preferences related to micromobility, telework, high occupancy vehicle and toll lane pricing, carsharing and vanpooling, and park and ride facilities. The key questions explored issues around perceived user barriers to different travel modes, impacts of teleworking on VMT, and impact of incentives or policy interventions on mode choice and travel behavior.

**6. Policy Modeling**

The research team used a policy modeling tool that combines three separate microsimulation modeling systems including UrbanSim, which models evolution of urban development and the location patterns of households and jobs; ActivitySim, which models daily activity schedules and travel demand; and BEAM, which models traffic flow. This modeling framework aims to capture a more realistic and complex interdependency between land use and transportation systems. This research focuses on a sensitivity analysis and a policy scenario analysis to quantify the potential of land use and transportation policies. The set of policies in this report was chosen in coordination with the CARB team and the capabilities of the model framework. The results show that combining policies results in greater reductions in VMT with a lower negative economic impact on travelers. The economic impact was calculated using a consumer surplus

metric. One of the policy scenarios that appeared to favor lower income populations was the increased density of housing and employment around transit centers, also referred to as Transit Oriented Developments (TOD). Increase in TOD led to decrease in VMT and increase in consumer surplus. For the elasticity results, the in-vehicle transit times stood out as an important factor in mode shift.

## III. STAFF COMMENTS

This project has been steered and overseen by CARB staff from the Research Division (RD), Sustainable Transportation and Communities Division (STCD) and from the Mobile Sources Control Division (MSCD). This project was impacted near its initiation by the COVID-19 shutdowns and the research team and CARB staff had to pivot to address changes in transportation trends and travel behavior. Staff from these three divisions helped steer the project objectives and methods. In particular, STCD provided significant direction in terms of choosing the policy levers to be analyzed through the survey and modeling methods. STCD staff also recommended that the modeling method initially proposed by the team be modified to include sensitivity analyses of different policy levers, to better understand travel behavior outcomes as a consequence of policy interventions. The research team provided an initial DFR to CARB in early April of 2023. CARB comments overall requested that the team improve the organization, clarity and writing style of the DFR. Staff specifically pointed out some missed opportunities to showcase work currently being done to address barriers identified. The most recent DFR provided to the RSC still has not addressed a large number of CARB comments and it is expected that the team will address the remaining comments in addition to the comments provided by the RSC.

## IV. STAFF RECOMMENDATIONS

Staff recommends the Research Screening Committee recommend that CARB accept with this draft final report  for $700,000.