STATE OF CALIFORNIA
AIR RESOURCES BOARD

MEETING OF THE
RESEARCH SCREENING COMMITTEE

-

September 4, 2026
10:00 a.m.

California 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, CA 95814
(916) 445-0753

September 4, 2026
10:00 A.M

Agenda

California Air Resources Board

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

May 5, 2026
10:00 A.M.

Minutes

Research Screening Committee Members in Attendance via Teleconference:

Dr. Aly Tawfik
Dr. Sam Silva
Dr. Bryan Hubbell
Dr. Thomas Bradley
Dr. Danae Hernandez-Cortez

I. Approval of Minutes of Previous Meeting

February 13, 2026

II. Discussion of Draft Final Reports

1. "Long-Term Chemical Characterization and Source Apportionment of PM2.5 in the San Joaquin Valley," University of California, Davis, $950,000, Contract No. 22RD038

   CARB staff presented a summary of the report to the Research Screening Committee (Committee). The Committee found that the report was consistent with prior work and concluded that the results are scientifically robust and provide new insights into fine particulate matter (PM2.5) pollution in California's San Joaquin Valley (SJV). The Committee requested updates on publications using the dataset, and staff provided the current status of the manuscripts. The Committee also asked about the timeline for public data release and supported the California Air Resources Board's (CARB) explanation that the contractor should retain the ability to publish using the data before its public release. The Committee approved the Draft Final Report (DFR) without any changes, contingent upon all data being made publicly available after the contractor's manuscripts are published. The Committee further recommended that, upon receipt of the data, CARB conduct a comprehensive review before releasing it on its website in an approved format and structure.

Motion: Move to recommend that CARB accept the report, subject to the inclusion of revisions based on comments from the Committee.

The Committee approved the motion.

2. "State of Zero-Emission Vehicle Secondary Market and Accessibility Impacts in California's Underserved Communities," University of California, Davis, $500,000, Contract No. 22STC016

   During the February 13, 2026 Committee meeting, staff presented an initial version of this final draft report to Committee. Overall, the Committee supported the project but voiced concerns with the sample size used for the survey and the usage of ChatGPT and asked that the report be brought to the following Committee meeting for further review.

   Staff returned to the May 5th, 2026 meeting to present on changes made to a subsequent version of the draft report. Staff presented a high-level overview of the goals of this project and explained some of the changes included in a subsequent draft. The Committee voiced their support for the project but continued to voice concerns over the sampling for the survey, emphasizing concerns that the conclusions developed in this report cannot be applied to a broader population. The Committee recommended approval with changes, requesting a disclaimer be added to beginning of the document describing how the findings and policy recommendations can and cannot be used.

   Motion: Move to recommend that CARB accept the report, subject to the inclusion of a disclaimer and revisions based on comments from the Committee.

   The Committee voted to approve the motion.

IV. Other Business

1. Update on Research Planning

   Staff provided Committee members with an update on ongoing research efforts. This item did not require a vote.

Item No.: II.1
Date: September 4, 2026
Proposal No.: 2898-321

Staff Evaluation of a Research Proposal

Title:	Closing the Soil NOx Gap: Quantifying the Roles of Agronomic Management and Canopy Processes with Long-Term Eddy Covariance Observations and Intensive Measurement Campaigns
Contractor:	University of California, Irvine
Principal Investigators:	Alex Guenther, Ph.D. Michael Kleeman, Ph.D.
Budget:	$1,750,000
Contract Term:	36 Months

For further information, please contact Kerri Steenwerth at (279) 208-7842

I. Summary

Uncertainties in soil-derived nitrogen oxide (NOx) emissions, particularly in the San Joaquin Valley (SJV), limit the ability to assess their contribution to ozone and fine particulate matter formation. The Subject Matter Expert Review Panel (SMERP) on soil nitrogenous emissions highlighted that long-term measurements and model evaluation for soil nitrogen oxide (NOx) emissions remain insufficient (*Horwath et al. 2025*). This underscores the need for more comprehensive observational data. In response, this project will deploy long-term, above-canopy eddy covariance (EC) systems to measure soil NOx emissions. It also will measure nitrous acid (HONO), ammonia (NH_3), and gaseous nitric acid (HNO_3), and characterize canopy uptake across dominant SJV agricultural systems. The expected results include robust, year-round datasets that quantify the magnitudes, drivers, and spatiotemporal variability of soil NOx emissions. The data are intended to help refine CARB's soil NOx emission modeling tools. These tools include the DeNitrification and DeComposition (DNDC) and the Model of Emissions of Gases and Aerosols from Nature, version 3 (MEGAN3). By comparing bottom-up estimates with top-down measurements, the project aims to

evaluate and refine biogeochemical models that inform critical State Implementation Plan efforts.

II. Technical Summary

Objective

The project's overall objective is to develop numerical model estimates of soil-derived NOx emissions from dominant SJV agricultural types and management practices by conducting long-term, field-based measurements and integrating them into CARB's soil NOx modeling frameworks. The project directly addresses SMERP recommendations by: 1) collecting year-round, continuous soil NOx fluxes; 2) quantifying processes that control canopy NOx uptake; and 3) expanding measurements of HONO and other nitrogenous gases. The goals are to support advancements in CARB's soil NOx emission modeling tools and reconcile differences between bottom-up inventories and top-down airborne and satellite estimates.

Background

Biogenic emissions of reactive N compounds, including NOx and HONO, are inputs to CARB's air quality models. In the SJV, published estimates of biogenic NOx emissions differ widely, underscoring the need for field-based measurements that capture effects of seasonality, management, and landscape-scale differences on gaseous N emissions across major agricultural systems. Further, the SMERP report on soil NOx highlights uncertainties in global and regional estimates of soil-derived NOx emissions (*Horwath et al., 2025*).

This project addresses these uncertainties by collecting long-term, continuous observations of NOx from representative croplands in the SJV. Intensive campaigns also will investigate canopy N uptake processes and HONO emissions to assess reactive N exchange between soils and the atmosphere. The data will be incorporated into the MEGAN3 modeling framework to expand representation of soil NOx emissions in air quality model simulations and address uncertainties in CARB's air quality planning tools.

Project Summary

The five coordinated tasks will be finalized in consultation with CARB.

Task 1. Field Study and Modeling Plan Development

The contractor will develop a detailed Field Study and Modeling Plan that defines measurement strategies, modeling approaches, and site selection across representative cropland in the top agricultural counties in the SJV (Fresno, Tulare, and Kern Counties). Three long-term EC towers will capture NOx fluxes from croplands using representative management practices. The plan will finalize site selection and outline instrumentation requirements, pre-deployment testing, sensor calibration and validation methods, data management procedures, standardized data cleaning and QA workflows, and gap-filling methods to ensure continuous and high-quality datasets. The plan will describe characterization of environmental drivers, soil attributes and nutrient dynamics, management practices and site conditions, and any relevant contingencies.

Further, an intensive field campaign will characterize the NOx canopy reduction factor (CRF) impact and HONO contributions to total reactive N emissions, as well as HNO_3, NH_3, volatile organic carbon (VOC), and total hydroxyl radical (OH) reactivity.

The plan will define the model testing framework that integrates all available observations into a unified testbed to support development of model parameterizations and enable comparisons between bottom-up and top0down NOx estimates. The contractors will describe the approach to evaluate soil emission and canopy uptake algorithms and refine SJV-specific emission factors.

Ongoing partnerships with industry groups and commercial SJV farm operations will be leveraged to establish flux sites. Further, the contractors will identify and pursue opportunities to collaborate with CARB partners and stakeholders engaged in complementary research on NOx emissions in the region.

Task 2. Initiate and Perform Field Measurements

Following CARB approval of the Field Study and Modeling Plan, the contractors will deploy EC towers and supporting instruments. The Contractor will operate systems to obtain six (6) site-years of NOx flux observations and measure soil nutrient dynamics. Contractors will follow the Field Study Plan for the continuous EC measurements, soil sampling, and the intensive field campaign.

Task 3. Data Collection, QA/QC, Dataset Constructions, and Archiving

All collected data will undergo standardized QA/QC procedures. Raw and processed data will be archived with complete metadata, generating final datasets that are suitable for MEGAN3 and DNDC models.

Task 4. Data Analysis and Model Development

Results from the three cropland sites will be used to investigate primary sources and drivers of NOx fluxes into the above-canopy atmosphere. Because above-canopy fluxes reflect net exchange rather than individual sources or sinks, model evaluation will consider soil NOx emissions, canopy reduction/deposition and transformation, and background regional NOx deposition. The analysis will test how well the models reproduce observed daily and seasonal cycles and quantify sensitivity of the residuals to environmental drivers, such as soil moisture, temperature, and time-since-fertilization or soil rewetting. The resulting error attribution will identify parameters and model components requiring further evaluation and development. Soil N and carbon dynamics will be used to assess model behavior across varying agronomic management practices.

The contractor will advance a modeling framework that integrates mechanistic models with machine-learning methods. Updated soil NOx emissions and canopy-reduction factors will be integrated into MEGAN3 and used to estimate NOx and HONO emissions. The observations will be evaluated against the testbed of other relevant NOx observations (e.g., surface, aircraft, satellite data) to assess the model predictions.

Task 5. Final Data, Data Publication, Tower Removal, Draft and Final Report

The contractor will deliver all data, documentation, and analysis workflows to CARB. Draft and final reports and a one-page public outreach document will be prepared based on CARB guidelines. All equipment will be removed from the field sites, which will be restored to a state comparable to conditions prior to installation.

III. Staff Comments

Research Division (RD) staff have reviewed the project, and client division staff have been engaged in the development of the project, pre-proposal selection, and proposal development.

CARB believes that the Principal Investigator, Dr. Alex Guenther, is well-qualified to lead this research project. Dr. Guenther has decades of experience measuring biogenic fluxes at multiple scales and integrating those observations into emission models for reactive N and VOCs. He is the lead developer of the MEGAN biogenic emissions framework used globally, and his work has directly contributed to soil NOx and HONO emission algorithms relevant to agricultural landscapes. Co-PI Kleeman has previously partnered with agricultural operators in CARB funded studies and modeled soil NOx emissions in California.

The research team has specialized expertise that aligns with each project component. It has a record of successful field deployments, advanced instrumentation development and application, model integration activities and relevant research publications. They have experience in analysis of soil characteristics, developing N emission modeling tools, the CMAQ model, aircraft-based trace gas mapping, and data integration. Their past contributions to CARB supported work and ongoing involvement in national research programs demonstrate their ability to carry out a project of this scope and complexity.

IV. Staff Recommendation

Staff recommend that the RSC advise CARB to approve the proposal for $1,750,000, contingent upon incorporating the additions and revisions identified by staff and the Committee.

Item No.: III.1
Date: September 4, 2026
Contract No.: 23RD003

Staff Evaluation of a Draft Final Report

Title:	Quantifying and Valuing Cancer Risks Associated with Air Toxics Exposure
Contractor:	Industrial Economics, Incorporated (IEc)
Principal Investigators:	Henry Roman, M.S.
Budget:	$484,163.22
Contract Term:	30 Months

For further information, please contact Pradeep Prathibha at (279) 208-7565

I. Summary

California regulates toxic air pollutants, including TACs 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, as well as rules to reduce exposure to localized sources of air toxics, including metal plating operations. CARB currently estimates reductions in cancer risks due to regulations that reduce toxic air pollutant emissions. CARB typically expresses benefits related to TACs control in terms of reductions in cancer risks (per million persons exposed) or as changes in populations exposed to particular risk levels. CARB currently is limited in its ability to express these benefits in monetary terms.

The objective of this project is to develop a peer-reviewed method to quantify and monetize health risks associated with TACs at the state, regional, and local levels. The method provides three approaches to translate cancer risk estimates into the numbers and types of cancer cases based on specific air toxics and then assigns a monetary value to those cases. To develop this approach for valuation the researchers adapt a peer-reviewed method for bridging from the individual type of risk assessments used in regulatory policy development to population level risk assessments needed to

perform benefits analysis. As carefully explained in the report, the contractors use a method of estimating cancer risk and valuation based on population-wide average exposures rather than individual-level lifetime exposures considered in the Office of Environmental Health Hazard Assessment's (OEHHA) health risk assessments. The method uses California-specific data and builds on approaches published in peer-reviewed journals and utilized by regulatory and scientific agencies like the U.S. EPA. The project also produces Python scripts and spreadsheet templates, along with the corresponding user guidance. These approaches are intended to inform and supplement the existing risk assessments conducted by CARB for purposes of valuation and are not intended to replace risk assessments performed for other purposes.

Regulatory/Policy Implications

The approaches in this project equip CARB with a California-specific methodology to quantify and monetize cancer incidents associated with TAC exposures. This capability could also inform CARB's regulatory health impact analysis, which currently estimates health effects associated with fine particulate matter ($PM_{2.5}$), which includes diesel particular matter (DPM), an air toxic. The project results offer a beta version of the framework for quantifying and valuing cancer risk, which will need further validation before consideration for use in regulatory assessments. Staff will coordinate across CARB Divisions and OEHHA to identify the validation needs.

II. Technical Summary

Objective

The objective of this research project is to develop a methodology to quantify and monetize cancer cases associated with exposures to toxic air pollutants in California.

Background

CARB is working to improve its characterization and monetization of cancer risks associated with exposure to TACs. CARB regulates air toxics such as benzene and DPM to protect public health and reduce the incidence of cancer and other adverse health

effects in the State and undertakes rulemakings to address statewide or regional exposures to these pollutants.

CARB conducts risk assessments for proposed regulations using toxicity factors developed by OEHHA for the cancer or non-cancer impacts of air toxic compounds. CARB typically expresses benefits related to air toxics control in terms of reductions in cancer risks (per million persons exposed), or as changes in populations exposed to particular risk levels. CARB currently is limited in its ability to express these benefits in monetary terms. CARB solicited this research to develop approaches for TAC risk characterization that are suitable for and compatible with methods for regulatory benefits assessment and economic valuation. This project aims to support CARB efforts to quantify and valuate cancer risks associated with exposure to TACs based on population-wide average exposures, California-specific data, and population subgroup (e.g., race, ethnicity) analysis.

Project Summary

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

The Contractor performed a comprehensive literature review to identify: 1) existing economic analysis approaches to quantify possible cancer cases based on cancer risk estimates associated with TAC exposure; and 2) existing methodologies to monetize fatal and nonfatal cancer health outcomes at different stages of life. The review focused on methods that can be applied to TACs with varying levels of uncertainty in their carcinogenic potential to humans. The Contractor conducted thorough reviews of 24 articles that met the inclusion criteria. In an annotated bibliography, the Contractor summarized key themes and concepts for consideration by CARB when developing a comprehensive and adaptable framework for quantifying and valuing health risks from air toxics.

In evaluating the health benefits of a rule, CARB currently uses risk assessment to quantify lung cancer risk reductions from decreased toxics exposure. If the rule is for DPM reductions, CARB would also analyze reductions in premature mortality and morbidity related to broader $PM_{2.5}$ decreases. The report highlights several

opportunities to apply bridging methods that support economic valuation of population-wide cancer risk from average exposures rather than valuation of individual risk from lifetime TAC exposure. The approaches translate population risk to numbers of fatal and non-fatal cancer cases and apply valuation estimates at the statewide or regional level. The report also emphasizes that the method developed for population risk and valuation calculations serves a different purpose than CARB's current risk analyses and should be considered a supplemental evaluation.

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

The contractor developed a methodology with three approaches to convert cancer risk estimates to possible cancer cases based on the literature review in Task 1. The three approaches accommodate different levels of data availability to evaluate cancer types and cases for each TAC. The contractors also provided a decision tree to help CARB staff identify which approach, or combination of approaches, is best suited for a given TAC based on available resources and risk management objectives. Approach I is suited for localized risk impacts and relies on individual cancer risk estimates as well as data on uncertainty and variability in exposure parameters and cancer potency. Approaches II and III are suited for TACs with regional or statewide exposures and produce population average estimates of fatal and non-fatal cancers. Approach II uses data including: central tendency exposures and cancer risks from modeling data, central tendency cancer potency and uncertainty based on animal studies, state historical cancer incidence, and survival data. Approach III uses data including: central tendency exposures and cancer risks from modeling data, central tendency and uncertainty and variability in cancer potency from epidemiological studies, state cancer fatality data, and cancer survival data.

Task 3. Monetization of Cancer Health Outcomes Methodology

The Contractor developed an approach building on existing methods used by U.S. EPA and the Organization for Economic Cooperation and Development (OECD) to determine the monetization for cancer cases, including willingness-to-pay (WTP) to avoid illness, cost of illness, and indirect costs such as lost productivity. Recent research published by LaPenta et al. (2024) and proposed adaptations by IEc support the

monetization estimates. The approach distinguishes between fatal and non-fatal cancer risks and accounts for the timing of exposures and diagnoses. It uses the value of a statistical life (VSL) that is standard practice in health analysis for valuing fatal cancer risks.

In brief, the contractors estimate the value of a one-in-one million reduction in non-fatal cancer risk (VNR) by year and cancer type using income growth-adjusted WTP; then, they estimate the change in non-fatal cancer diagnoses, also by year and cancer type, to monetize the benefits of reduced exposures from air toxics controls. For fatal cancers, the contractors express morality risk as the value of one-in-one million reduction in mortality risk (VMR) by year using income growth-adjusted VSL. They estimate the change in premature deaths by year to monetize the benefits of air toxics controls.

For Approach I, the contractors estimate the cancer-specific and population subgroup-specific value to society from risk reduction per person exposed, which is consistent with CARB's TAC risk assessment and uses California-specific data for cancer incidence, demography, and income. For valuing population-wide changes in cancer risk, as in Approach II and III, the contractors estimate and monetize the number of avoided fatal and non-fatal cases by cancer type based on changes in ambient TAC levels, producing county-stratified annual monetized benefits by age, race, and sex. As the benefits of reduced TAC exposures occur years after costs of control programs are incurred, the contracts also apply a 2% discount rate consistent with U.S. Office of Management and Budget and U.S. EPA recommendations.

The deliverables include a decision tree to help identify the approach best suited for a given TAC and risk-assessment scope, an Excel file for entering run inputs, a data file with the required approach inputs, and a Python script (.py) for running the TACs analyses for each of the three approaches.

Task 4. Peer Review

In this task, the Contractor conducted three case studies (one for each approach in the monetization framework for TACs selected in consultation with CARB and OEHHA staff)

demonstrating how to quantify and value fatal and non-fatal cancer risks from TAC exposures. The three proof-of-concept case studies focus on localized DPM (Approach I), formaldehyde (Approach II), and statewide DPM (Approach III).

Case study #1 estimates cancer risk reductions from decreased emissions of DPM from CARB's 2022 regulation on Transport Refrigeration Units (TRUs). It uses approach #1 and applies CARB's one-in-one-million cancer risk value to CARB's estimated reduction in cancer risks from mobile TRUs operating outside grocery stores. The results present the monetized benefits of a one-in-one-million reduction in lifetime lung cancer risk for an individual.

Case Study #2 develops monetization estimates for cancer risk reductions associated with a hypothetical 40% reduction in emissions of formaldehyde, which OEHHA identified as a toxic air contaminant in 1998. This case study uses approach #2. Toxicological studies and human occupational epidemiology studies have shown that prolonged inhalation exposure to formaldehyde is linked to cancer. OEHHA's inhalation unit risk (IUR) and cancer potency factor (CPF) values are based on animal studies. The case study follows the basic steps of risk assessment, hazard identification, exposure assessment, dose–response analysis, and risk characterization, but adjusts certain assumptions and inputs to serve as "bridges" to a socioeconomic benefits analysis. It also adds a valuation step that applies monetary values to the quantified health benefits of formaldehyde emission reduction.

Case Study #3 develops valuation estimates for cancer risk reductions associated with a hypothetical 40% statewide decrease in DPM emissions. The case study uses approach #3. The study follows the standard steps of risk assessment based on epidemiological studies but modifies certain assumptions and inputs to serve as "bridges" to a socioeconomic benefits analysis. It also adds a valuation step that assigns monetary values to the quantified health benefits of the DPM emission reduction.

The case studies were then submitted for peer review by the following expert panel, also selected based on recommendation from CARB and OEHHA staff:

1. Dr. Elizabeth Chan, PhD, Senior Science Advisor, currently with U.S. EPA's National Center for Environmental Economics (NCEE), formerly worked in EPA's Office of Air Quality Planning and Standards and Office of Research and Development.
2. Dr. Daniel Axelrad, independent consultant and former Environmental Scientist in U.S. EPA's NCEE.
3. Dr. James Hammitt, PhD, Professor of Economics and Decision Sciences at Harvard University Chan School of Public Health

The peer reviewers provided thorough and supportive feedback. The reviewers commented that the proposed methods generally align with best practices for population-scale cancer risk assessment and they did not identify significant issues with the overall approach or methodology. They noted that valuation techniques were sufficient for nonfatal cancer risk given the limited WTP studies available. The requested revisions included clarifying when each approach should be applied and addressing how to handle negative values in the estimated WTP for nonfatal cancers. In response, IEc revised the report to explain the applicability and logic for using each method, provided a detailed explanation of negative nonfatal WTP values, and clarified their application in the context of cancer risk assessment.

III. Staff Comments

This report was reviewed by multiple staff members from CARB (RD, AQPSD, TTD) and OEHHA. CARB and OEHHA staff requested a detailed explanation and documentation of the code and data templates; description of input datasets, including guidance on how to update them in future analyses by CARB staff; and clarification on when to use the three approaches. Staff asked for revisions explaining how the contractor developed population distributions from OEHHA's CPF/IUR values and further refinement of the DPM-related cancer risk characterization. Staff additionally requested illustrative examples throughout the report. The contractors revised their report accordingly. They clarified and improved the documentation for the code and data templates, created a comprehensive data dictionary, and clearly explained how to prepare input data. They also expanded on the applicability for using each approach

and generally revised the report for clarity. Overall, the contractor addressed comments from staff and peer reviewers to the extent feasible given the remaining time and budget and provided detailed responses to reviewers. The contractor explained that this methodology is a beta version designed to be flexible by using input templates. However, because it was built using only a small number of case studies, additional validation is needed before regulatory applications.

Aside from these changes, the report generally met contract criteria.

IV. Staff Recommendation

Staff recommend that the RSC advise CARB to approve the report, contingent upon incorporating the additions and revisions identified by staff and the Committee.

Item No.: III.2
Date: September 4, 2026
Contract No.: 22RD005

Staff Evaluation of a Draft Final Report

Title:	Children's Health and Air Pollution Study: Standardized Assessments, Attention and Cognition in California Kids (CHAPS: STACK)
Contractor:	University of California, Berkeley
Subcontractors:	University of California, San Francisco Central California Asthma Collective
Principal Investigators:	Elizabeth M. Noth, Ph.D. Nina Holland, Ph.D. Stephanie Holm, M.D., Ph.D., M.PH.
Budget:	$499,976
Contract Term:	36 Months

For further information, please contact Pradeep Prathibha at (279) 208-7565

I. Summary

This contract was developed to inform CARB's efforts to update and expand health endpoints used in the health impact analysis of CARB rulemakings and programs. CARB quantifies twelve adverse health endpoints associated with $PM_{2.5}$ exposure. These health endpoints are premature death from cardiopulmonary disease, hospitalizations and emergency department visits for heart- and lung-related causes, asthma onset and symptoms/exacerbation, lung cancer incidence, nonfatal acute myocardial infarction, work loss days, Alzheimer's disease, and Parkinson's disease. Research has shown that numerous adverse health effects are associated with exposure to a variety of criteria pollutants and toxic air contaminants. In April 2020, CARB adopted Board Resolution 20-13 directing staff to expand their methodologies to include additional air pollutants and health endpoints. Per this Resolution, this contract supported a study evaluating additional endpoints related to neurodevelopmental outcomes in children.

The project aimed to quantify and monetize neurodevelopmental outcomes associated with exposure to air pollution. Specifically, the project developed statewide associations between annual average $PM_{2.5}$, NO_2, O_3, and traffic exposures with standardized test performance as well as the associations between lifetime exposure to multiple pollutants with cognition and attention in the San Joaquin Valley (SJV). The latter leveraged datasets from the Children's Health and Air Pollution Study (CHAPS) longitudinal cohort previously established by the research team with now-terminated federal grants.

The study found that in the statewide models, higher $PM_{2.5}$, O_3, NO_2, and DPM were associated with a lower percentage of students meeting state standards in English Language Arts (ELA) and Math scores, with stronger associations for exposures two years prior to testing and for younger grade levels. The researchers also reported negative association for $PM_{2.5}$ and O_3 exposures and standardized test scores for math in the SJV CHAPS study population. In case of a hypothetical intervention to lower statewide $PM_{2.5}$ exposures to 7 $\mu g/m^3$ or below, researchers estimated that elementary Smarter Balanced Assessment Consortium (SBAC) scores would rise by up to 22.6 points. These findings add to a growing body of evidence that air pollution exposure affects not only children's physical health but also their cognitive development. Results from this contract will inform CARB's ability to evaluate the effects of its policies and programs, including a wider range of public health benefits.

Regulatory/Policy Implications

This study developed California-specific quantitative estimates of associations between exposure to air pollutants and neurodevelopmental outcomes in California and the SJV. Analyses were stratified by race/ethnicity and sex, with socioeconomic status and age included as covariates. The diverse study population allowed for examination of health effects in racial and ethnic subgroups in addition to effects for overall statewide population. These associations will inform CARB's regulatory health impact analysis and provide a more comprehensive understanding of the quantified public health benefits of CARB rules and programs., including in low-income communities. Moreover, this study identified gaps in epidemiological evidence on air

pollution exposure and neurodevelopmental health that CARB could investigate in future research.

II. Technical Summary

Objective

The main objective of this study was to increase understanding of neurodevelopmental effects in children in association with exposure to air pollutants throughout California, including within racial and ethnic groups. A specific aim was to develop California-specific concentration response functions between exposures to air pollutants and children's standardized test performance.

Background

Evidence from epidemiologic and experimental studies reports positive associations between long-term $PM_{2.5}$ exposure and neurodevelopmental effects. The U.S. EPA in their 2019 ISA concluded that the collective evidence is "suggestive of a causal relationship." There is growing scientific evidence that prenatal and early life exposures to air pollutants are associated with children's neurodevelopmental effects. These effects can include learning disabilities, such as lower intelligence, reduced attention, and memory problems. Other important impacts include developmental delays that affect cognitive function and behavior. However, current evidence is limited and does not clearly show California-specific associations between air pollution and children's neurodevelopmental outcomes.

Project Summary

<u>Task 1: Systematic Review of Childhood Air Pollution Exposure and Child/Adolescent Standardized Test</u>

The researchers performed a systematic literature review of air pollution exposure during childhood and effects on standardized test performance in children and adolescents. The researchers reviewed 29 full-text articles, of which 5 met the inclusion criteria. The review suggested small and inconsistent trends of decreases in standardized test scores with higher exposure to criteria pollutants, polycyclic aromatic

hydrocarbons, and certain air toxics. The review also identified potential confounding variables to be considered in future research including, socio-economic status, school district funding, and student absences. The limited epidemiological and ecologic studies identified in the systematic review highlighted the need for additional individual-level studies on children's individual test score outcomes and air pollution exposure.

Task 2: Statewide Association between $PM_{2.5}$, NO_2, O_3, and Traffic Exposures and Standardized Test Performance

The researchers examined the associations between average annual air pollutant concentrations at school sites ($PM_{2.5}$, NO_2, O_3, DPM, and traffic exposures) with 1-year and 2-year lags and the performance of California public schools on standardized tests in ELA, Math, and science scores between 2014 to 2019. The analysis used data from nearly four million students, summarized at the school level. The results found that higher levels of $PM_{2.5}$, O_3, NO_2, and DPM were associated with a lower percentage of students meeting state standards in ELA and Math. Specifically, a 2.43 $\mu g/m^3$ increase in $PM_{2.5}$ was associated with 4.35% fewer elementary school students achieving state standards, while a 3.36 ppm increase in ozone was associated with 3.61% fewer elementary students meeting state standards. The strongest associations appeared in younger students, and there were no notable differences by sex in the associations across all pollutants and age groups. Analyses across exams indicated that standardized test performance in science was not as affected as those in English and math.

Task 3. Lifetime Exposure to Multiple Air Pollutants, Cognition and Attention, in the San Joaquin Valley

The researchers investigated the relationship between multiple pollutants ($PM_{2.5}$, O_3, NO_2, NOx, PAH456 [4-, 5-, and 6-ring PAH compounds] and elemental carbon) and multiple years of standardized test scores in the long running CHAPS cohort, which included 193 children from the SJV. The children were enrolled prenatally or as early elementary school students and have been followed for 5–10 years. Assessments

included neurodevelopmental and cognitive measures, social and emotional health surveys, standardized test scores, and biomarkers from blood and urine.

Results indicated that math standardized test scores were negatively associated with O_3 and $PM_{2.5}$, but not NO_2, and ELA scores had a weak negative association with $PM_{2.5}$ and O_3. Third-grade SBAC scores showed strong correlations with the NIH Toolbox total and language-knowledge (vocabulary skills) measures and a moderate correlation with serum Brain-Derived Neurotrophic Factor (BDNF). First-trimester exposures to traffic-related air pollutants ($PM_{2.5}$ and PAH456) were associated with elevated childhood z-scores for aggressive and rule-breaking behavior. Exposure during the first year of life to all pollutants was consistently associated with lower serum BDNF levels. The research also identified a critical window around 5–6 months of age corresponding to a decrease in NIH Toolbox total cognition scores. Overall, early-life exposure to ambient air pollution induces persistent neurocognitive and behavioral alterations extending into adolescence.

Task 4. Projected Economic Benefit to California of Decreasing Air Pollutant Effects on Cognition

In this task, researchers estimated how much standardized test scores could improve if California air pollution levels were lowered. The G-computation results from the Putative Air Pollution Interventions analysis suggested that a strong intervention to lower all statewide pollution to 7 μg/m³ or below could raise elementary standardized test scores by as much as 22.6 points. No studies have directly connected SBAC scores to IQ, but to estimate monetized benefits, the researchers assumed that SBAC scores followed the same link to lifetime earnings as IQ does, thereby estimating that an average improvement of 9.71 points in SBAC scores (equal to 0.092 standard deviations) might raise lifetime earnings by about $14,852 on average. The researchers urged extreme caution in interpreting or using this monetization in public health applications.

Task 5: Outreach and Reporting

The researchers worked with the CHAPS Community Advisory Board in the SJV to reach out to the community. They published one peer-reviewed journal article about the STACK project and a second paper is now being prepared to submit within the next quarter. The research team shared their findings at a conference in San Joaquin Valley (Air Quality and Health in Merced, California, October 2024). The community outreach team provided materials to the CHAPS community, the study participants, and the public. The research team and the Central California Asthma Collaborative (CCAC) kept the study participants and current CHAPS cohorts informed through return visits and Public Outreach Document (flyer and slide deck). This document is also available on the CCAC website. Along with the researchers, CCAC is working to produce Spanish version of this Document, and the CCAC will present the research findings to SJV Community Steering Committees through the fall of 2026.

III. Staff Comments

CHAPS examined how air pollution affects children's health by analyzing blood and urine markers of inflammation and measuring lung function and body mass to assess indicators of asthma and pre-diabetes over 10 years in SJV using federal funding. Recent federal funding cuts resulted in the loss of research staff and project changes, delaying completion of the study and submission of the final report.

Task 3 of the CHAPS SJV deliverables had several deviations from the original analysis plan for the following reasons: the researcher was unable to obtain information from families about individualized education programs or other neurodevelopmental diagnoses, so two alternative outcomes were used; too few participants had science exam results to support analysis; field staff expressed concerns that some questions in the longer youth self-report tool might cause distress, so those items were not used; federal funding cuts reduced staff and analytical tools, so the researcher analyzed three pollutants with a linear mixed model instead of nine. CARB will consider tasks to attain the complete outcomes expected from the original analysis plan in future research activities.

Despite these challenges and delays, the researchers remained committed to completing the report. Due to staff reductions and time constraints, the main text of the draft final report is brief; the appendices, which are journal articles drafted or already submitted for peer review by the researchers, cover the main scientific content. This report was reviewed by multiple staff members from CARB (RD, AQPSD), OEHHA, and one staff member from the California Department of Public Health.

Reviewers asked for more detail on the use of ecological analysis and pointed out that the report should explain how the land use regression-based datasets for $PM_{2.5}$ and O_3 were used during wildfire events, and how DPM emissions were included in the exposure analysis. The reviewers requested clearer explanations of the tasks, better organization and formatting of the report, stronger connections between the different Tasks, and additional background on how the findings could help CARB's health analyses. Overall, the reviewers acknowledged that the report clearly discusses the limitations of the SJV study, including the CHAPS cohort's small sample sizes, uncertainties in monetized impacts on lifetime earnings based on SBAC scores, potential biases, and other uncertainties. Researchers addressed most comments and provided detailed responses to reviewers.

IV. Staff Recommendation

Staff recommend that the RSC advise CARB to approve the report, contingent upon incorporating the additions and revisions identified by staff and the Committee.