EXHIBIT A

SCOPE OF WORK

☒ Contract ☐ Grant

Does this project include Research (as defined in the UTC)? ☒ Yes ☐ No

PI Name: Jiayu Li

Project Title: Laboratory and Community Evaluation of Advanced Portable Air Cleaners and HVAC Filters for Indoor Gas Pollutants

Project Summary/Abstract

Advanced air-cleaning technologies – including activated carbon filters, chemically impregnated media, photocatalytic oxidation (PCO), ionization, and hybrid systems – offer potential solutions for removing indoor gaseous pollutants, but their real-world effectiveness and possible harmful byproducts are not well understood. This project will combine controlled laboratory experiments and community-based field studies to systematically evaluate a wide range of portable air cleaners (PACs) and HVAC filters for removing gas-phase indoor pollutants. First, the research team will review existing literature and commercially available products, then rigorously test **30 representative devices** in a full-scale environmental test chamber (≈2700 ft^3) and a wind tunnel. Performance metrics will include pollutant-specific clean air delivery rates (CADRs), energy use, and secondary emissions (ozone, volatile organic compounds, ultrafine particles) when devices are challenged with hydrogen sulfide (H_2S), nitrogen dioxide (NO_2), and a mixture of VOCs in the environmental chamber. Single-pass filtration efficiency and sorbent breakthrough times of the absorbing type filters will be evaluated in the wind tunnel. Next, the most promising and cost-efficient devices will be deployed in a **randomized controlled field study** across **45 homes** in three odor- and gas-impacted communities (in Lake, Fresno, and Kern Counties), recruited through community partners. Each home will participate in a 10-week trial, during which we will monitor time-resolved indoor NO_2, H_2S, and formaldehyde concentrations with calibrated sensors and collect time-integrated speciated VOC samples and survey occupants at four times during the baseline (Week 1), beginning and end of the intervention (Weeks 2 and 9), and post intervention (Week 10). Expected outcomes include identification of the most effective technologies for each pollutant, data on filter longevity and maintenance needs, and best-practice guidance on using air cleaners in homes and other buildings. The results will directly benefit the public and the State by informing CARB's Indoor Air Quality program and community mitigation efforts (e.g., in AB 617 environmental justice communities), providing science-based guidance to reduce exposure to odors and harmful gases indoors.

If Third-Party Confidential Information is to be provided by the State:

☐ Performance of the Scope of Work is anticipated to involve use of third-party Confidential Information and is subject to the terms of this Agreement; ***OR***

☐ A separate CNDA between the University and third-party is required by the third-party and is incorporated in this Agreement as Exhibit A7.

Scope of Work

Statement of Significance

Relevance to CARB and Environmental Justice

Indoor exposure to non-particulate pollutants like NO_2, VOCs, and H_2S is a growing concern for California's public health and environmental justice (Logue et al., 2011; Morello-Frosch et al., 2000; Pastor Jr. et al., 2006). These pollutants originate from outdoor sources (wildfire smoke, traffic emissions, oil/gas operations, landfills, geothermal and agricultural activities) as well as indoor sources (gas stoves, cleaning and personal care products, off-gassing building materials), and they pose serious health and comfort challenges. For example, in South Central Fresno (an AB 617-designated community in the San Joaquin Valley), residents face a high cumulative burden of NO_2 and toxic VOCs from heavy traffic and industrial operations (CARB, 2018). In Lake County's Big Valley Rancheria, tribal communities are impacted by chronic "rotten-egg" odors from Clear Lake's algal blooms and geothermal vents, with measured elevated H_2S levels, causing persistent odor complaints and respiratory symptoms (Blue et al., 2021; Chiu et al., 2015; Mioni et al., 2011). Likewise, neighborhoods in Kern County (e.g., Bakersfield) contend with frequent odors and hazardous gases from extensive oil production, dairy farms, and waste facilities (Jacobs, 2020). These pollution burdens fall disproportionately on low-income and minority populations, making effective gas-phase mitigation both an environmental justice and public-health priority.

Policy and Program Alignment

CARB has an active indoor air quality research program and regulatory interests in indoor pollution. However, knowledge gaps remain regarding which air filtration technologies work best for gases/odors and how to deploy them in vulnerable communities. Many advanced air cleaners marketed for gas removal (e.g., carbon filters, chemisorbents, PCO/ionizers) have highly variable performance (Li and Ma, 2021; Pei and Zhang, 2011). Recent studies have found that some oxidation-based devices remove far less VOC pollution than expected and can emit harmful byproducts like ozone and formaldehyde (Collins and Farmer, 2021; Link et al., 2024; Wang et al., 2022; Ye et al., 2021). Sorbent-based filters (activated carbon, etc.) are more reliable for pollutant removal, but their efficacy diminishes as the sorbent material becomes saturated (Pei and Zhang, 2010). There is also limited data on how laboratory performance translates to real homes with varying ventilation, humidity, and occupant behaviors. By addressing these uncertainties, this project directly supports CARB's goal to improve indoor air quality through science-based guidance. The results of this study will inform CARB's Indoor Air Quality program and multiple statewide initiatives, including incentive programs for AB 617 communities and Community Emission Reduction Plans, by identifying the best strategies to reduce indoor VOCs, odorous sulfur compounds, and other non-PM pollutants in impacted homes. The findings will be used by CARB and other agencies to develop improved guidance and mitigation strategies, potentially influencing updated building standards, community assistance programs, and wildfire smoke response

guidance for indoor environments. In summary, this project's objectives and deliverables are directly aligned with CARB's mission to protect public health, and it will provide tangible benefits for environmental justice communities by empowering them with effective tools to improve their indoor air quality.

Project Objectives and Overall Strategy and Approach

The goals of this research are to fill critical knowledge gaps and provide actionable solutions for indoor gas-phase pollution control. The specific objectives of the project are to:

Quantify the effectiveness of a broad range of air cleaning technologies in removing H_2S, NO_2, and VOCs from indoor air under controlled laboratory conditions and in occupied homes.

Compare the performance of different filtration and air-cleaning approaches – including activated carbon filters, chemisorbent-treated media, PCO/ionization units, hybrid systems, and others – in terms of pollutant removal efficiency, clean air delivery rate, energy use, and potential byproduct generation.

Measure retention capacity and longevity of sorbent-based filters (breakthrough time and adsorption capacity) and assess how frequently filters or media need replacement to maintain effectiveness for each pollutant.

Evaluate real-world effectiveness and user acceptability through field deployments in diverse communities, including assessing how pollutant reductions differ in occupied homes (with normal occupant behavior, ventilation, humidity, etc.) compared to lab predictions, and documenting any operational issues or user feedback (e.g., noise, odor reduction, maintenance requirements).

Analyze cost-effectiveness and equity considerations, including the operational costs (filter replacements, energy) of the most promising air cleaners, and determine how affordable and accessible these technologies are for residents in disadvantaged communities. This will inform whether subsidies or incentive programs might be needed for sustained use.

Develop practical guidance and outreach materials for stakeholders. This includes creating a best-practices guidance document or toolkit that CARB, households, schools, and facility managers can use to select appropriate air filtration solutions based on specific pollutant concerns (e.g., wildfire smoke VOCs vs. traffic NO_2 vs. odor from refineries). The guidance will be in plain language and will highlight recommendations for buildings with vulnerable populations (such as schools, senior centers, and childcare facilities in impacted areas). The final guidance will incorporate a one-page Public Outreach Summary of key findings and an Equity Implications discussion, ensuring the research benefits are effectively communicated to the public and specifically address impacts on priority communities.

To achieve the above objectives, the project will employ a two-tiered evaluation combining laboratory experiments with community field research. In the **laboratory tier**, we will use a full-scale environmental chamber and wind-tunnel tests to generate rigorous performance data for a representative sample of air cleaning devices. In the **field tier**, we will partner with community organizations to deploy the top-performing technologies in real homes located in historically impacted communities, using a randomized controlled trial design to isolate the effects of the

interventions. Data will be collected continuously via sensors and through periodic sample collection and surveys, then analyzed to compare technologies and derive conclusions about effectiveness, safety, and cost in real-world use. Throughout the project, we will follow best practices for quality assurance (calibrations, controls, replicates) and adapt our methods as needed if challenges arise. Potential challenges and mitigation strategies are discussed at the end of this section.

Project Tasks

Task 1: Literature Review. The project will begin with a comprehensive review of existing research, product literature, and standards related to gas-phase air cleaning. The research team will survey peer-reviewed journals, industry reports, and guidelines to establish the state of knowledge on key topics:

(a) Pollutants and health/odor thresholds – summarize typical indoor concentrations of H_2S, NO_2, and representative VOCs (e.g. those from wildfire smoke, traffic emissions, oil/gas operations, etc.), along with their known health effects, odor thresholds, and any relevant health-based exposure limits or guidelines.

(b) Air cleaning technologies – catalog the range of available technologies (activated carbon filters, chemisorbent-treated filters, PCO and ionizers/plasma devices, combination/hybrid systems, etc.), documenting their principles of operation and any manufacturer claims about performance.

(c) Performance evidence – compile data from prior studies on how well these devices remove specific pollutants (e.g., reported removal efficiencies for VOCs or NO_2, sorbent capacities for H_2S, observed breakthrough times, and saturation behavior). Special attention will be given to the technologies that are included in the CARB-Certified Air Cleaning Devices. Besides, any evidence of device failures or rapid performance degradation, and to reported byproduct emissions or safety concerns (for example, ozone generation by certain electronic air cleaners or formaldehyde production by PCO units).

(d) Costs and maintenance – gather information on the capital costs, replacement filter costs, energy consumption, maintenance requirements, and noise levels for different device types, as these factors will feed into later cost-effectiveness analysis.

(e) Regulations and standards – review any relevant standards or guidelines, such as ASTM WK81750 (a draft standard test method for chemical air cleaner assessment) (ASTM, 2025), ASHRAE Standard 145.2 (laboratory test method for gas-phase filters) (ASHRAE, 2025), UL 2998 (Zero Ozone Emission certification, requiring ≤5 ppb ozone), and California's regulation limiting ozone emissions from indoor air cleaners (≤50 ppb ozone).

The literature review will result in a summary report or table that identifies knowledge gaps and helps refine the experimental design in subsequent tasks. Before the experimental phase begins, the team will meet with CARB staff to **jointly select high-quality, representative devices** from each technology class.

Deliverable/output: Key findings from Task 1 will be summarized in the Draft Final Report (providing context and justification for the chosen test methods, pollutants, and technologies) and will inform the selection of devices for Task 3.

Task 2: Community Selection, Engagement, and Recruitment. In parallel with the literature review, the team will initiate community engagement efforts to lay the groundwork for the field study. We have identified **three impacted communities** that represent diverse non-PM pollution challenges in California, each corresponding to a different predominant pollutant source profile:

- **Big Valley (Lake County):** A tribal community (Big Valley Band of Pomo Indians, near Clear Lake) affected by chronic "rotten egg" odors (elevated H_2S) from recurring harmful algal blooms in Clear Lake and natural geothermal seeps. Residents have long reported strong sulfur odors and associated health symptoms in their homes.

- **South Central Fresno (Fresno County):** An urban, disadvantaged community in the San Joaquin Valley facing elevated NO_2 and toxic VOC levels due to heavy traffic (multiple freeways and railyards) and nearby industrial and agricultural operations. This area is designated as an AB 617 community with ongoing community-led air quality improvement efforts.

- **Kern County (Kern County):** Rural and semi-urban neighborhoods downwind of oil refineries, petroleum extraction fields, large dairies, agricultural waste burning, and wastewater treatment plants. Residents frequently report strong odors (H_2S, petrochemical VOCs) and poor air quality in their homes.

For the field study, 15 homes will be recruited in each of these three areas (a total of 45 homes). We will collaborate closely with community-based partners to ensure culturally appropriate and effective engagement. Tracking California (a program of the Public Health Institute) will serve as the statewide coordinator for community outreach and data tracking. Our on-the-ground partners include the Big Valley Band of Pomo Indians in Lake County and the Central California Environmental Justice Network (CCEJN) in Fresno and Kern Counties. Together, the team will carry out the following sub-tasks:

Task 2.1: Community Outreach – Tracking California and UC Berkeley will draft outreach materials (flyers, consent forms, survey instruments, plain-language summaries), which will then be vetted by CCEJN and Big Valley Band of Pomo Indians staff embedded in communities. Community partners (CCEJN and Big Valley Band of Pomo Indians) will review our study materials (recruitment flyers, consent forms, survey instruments) to ensure they are culturally competent and understandable and will advise on any community-specific considerations (such as appropriate incentive structures or scheduling constraints around local events).

Task 2.2: Participant Recruitment – CCEJN (for Fresno and Kern) and the Big Valley tribal environmental office (for Lake) will lead the recruitment of households. Recruitment will prioritize households that: (a) are located nearest to major pollution sources of interest (e.g. within a certain distance of a refinery, highway, or lake shoreline), or (b) have sensitive individuals (such as asthmatic children or elderly occupants) who could particularly benefit from cleaner indoor air. Recruitment methods will include bilingual flyers at local community centers, announcements on social media (including Spanish-language outlets), door-to-door outreach by community health

workers, and leveraging existing networks (such as tribal newsletters or neighborhood associations). Our goal is to enroll a sample of homes that is representative of each community's population (including renters and owners, mix of housing types if possible) while focusing on those most affected by odors and emissions. Each participating household will receive a modest financial incentive (gift cards or equivalent) and, importantly, an individualized "report-back" of their indoor air quality results at the end of the study (to reward participation and provide a direct benefit). We will aim to secure 15 confirmed participant homes in each location; if interest exceeds that number, additional homes will be waitlisted or included as backup. Informed consent will be obtained from all participant households, and Institutional Review Board (IRB) approval will be obtained through UC Berkeley for all research activities involving human subjects (e.g., home environmental monitoring and surveys) before field work begins. All recruitment and data collection protocols will adhere to IRB requirements to protect participant confidentiality and welfare.

Task 2.3: Training and Deployment Preparations – The research team will develop training materials and protocols for the field study to ensure consistency. This includes an installation guide for the air cleaning devices (for both PACs and any HVAC filter upgrades) and standardized procedures for sensor deployment and sample collection in homes. Tracking CA and UC Berkeley will develop standardized guidance for the community field staff (from CCEJN and Big Valley) on how to set up the equipment in homes, administer the surveys, and troubleshoot any basic issues. We will also finalize the randomization scheme (described in Task 4 below) and assign each enrolled home to a study group. By the end of Task 2, we expect to have the first batch of ~15 homes consented and scheduled, with a clear plan for rolling out the field interventions.

Task 3: Laboratory Evaluation of Air Cleaning Technologies. This task involves controlled experimentation in the lab to characterize the performance of selected air cleaning devices under reproducible conditions. We divide Task 3 into two components: **(3A) Chamber testing of full devices** (portable air cleaners and HVAC filter systems in a room-sized environment), and **(3B) Wind tunnel testing of filter materials** (to assess single-pass removal efficiency and sorbent capacity).

Task 3.1 – Chamber Testing: We will utilize the Center for the Built Environment (CBE)'s full-scale indoor environmental chamber at UC Berkeley. The chamber measures approximately 18 ft × 18 ft × 8.5 ft (≈2700 cubic feet) and is equipped with three independent HVAC air handling systems, giving us precise control over airflow, temperature, and humidity inside the chamber. This setup allows us to simulate a realistic room or small office environment and to test portable air cleaners (PACs) and in-duct HVAC filters under consistent conditions. We will select 30 devices spanning five technology classes (roughly 3–7 devices per class): (1) standard activated carbon filters and panels, (2) chemisorptive or treated sorbent media filters (e.g. carbon impregnated with potassium permanganate or other reactive agents), (3) photocatalytic oxidation units, (4) ionization/plasma air cleaners, including any that deliberately generate ozone or other reactive species, and (5) hybrid or multi-stage devices (for example, a PAC that uses a combination of a HEPA + carbon filter with an ionizer). Specific models will be chosen based on the findings of Task 1 (literature review) to ensure we test a range from low-cost consumer units to higher-end or specialized units, as well as both portable units and HVAC retrofit filters that can be mounted in residential air handling systems.

Chamber test protocol*:* We will follow, to the extent applicable, the draft ASTM WK81750 standard method for evaluating chemical air cleaner performance. In each chamber test, we will "challenge"

the device with a complex mixture of pollutants that represents real-world indoor air contaminant loads. This challenge mixture will include:

- **Hydrogen sulfide (H_2S):** to represent sulfurous odor pollutants (calibrated release to achieve a certain ppb level in the chamber).

- **Nitrogen dioxide (NO_2):** to represent traffic and combustion-related gases (dosed from a standard NO/NO_2 gas source).

- **Volatile Organic Compounds (VOCs):** a mixture of VOCs reflecting multiple sources. We will include a subset of VOCs from wildfire smoke (e.g., phenolics and furanics from wood smoke), petroleum-related VOCs (e.g., BTEX to mimic traffic or oilfield emissions), and odorous oxygenated VOCs (e.g., aldehydes). If a single mixture is too complex, we may perform separate runs for different VOC groups.

Each PAC or filter device will be placed in the chamber (for HVAC filters, installed in the chamber's air handling unit duct). We will introduce the pollutant mixture into the sealed chamber and allow it to mix to uniform initial concentrations. Then the device will be turned on (for PACs) or the HVAC system will be run with the test filter installed. We will continuously monitor pollutant concentrations and record the decay of each contaminant over time. Key instruments include: a Proton-Transfer-Reaction Mass Spectrometer (PTR-MS) for real-time speciated VOC and H_2S measurements, a Teledyne T200 chemiluminescent analyzer for NO/NO_2,, calibrated electrochemical sensors for formaldehyde, a GRIMM Mini-WRAS aerosol spectrometer to detect any generated secondary ultrafine particles (10 nm – 35 µm size range, which can indicate byproduct particle formation), and a 2B Technologies Model 205 ozone monitor for any ozone emissions. We will also collect integrated air samples during tests to later analyze and quantify a broader range of VOCs in a laboratory, ensuring the performance of the real-time instruments.

From each test, we will calculate pollutant-specific CADR (Clean Air Delivery Rate) in m^3/hour for H_2S, NO_2, and for grouped VOC categories. CADR is obtained from the decay rate constant multiplied by the chamber volume (accounting for natural decay or deposition if measured in a blank run). We will measure energy consumption of each device (using plug load power meters or built-in instrument readings for fan power) and note any operational issues (noise levels, malfunctions, etc.). After initial tests with new devices, we will later (in Task 4/5) re-test "aged" devices that have been used in homes, to see how real-use conditions impact performance (comparing fresh vs. used filters for changes in CADR, capacity, and byproduct emissions).

Task 3.2 – Wind Tunnel Filter Testing: In addition to full-room testing, we will conduct bench-scale tests on sorbent filter materials using a small wind tunnel or duct apparatus. This will involve taking samples of filter media (e.g., a section of activated carbon filter) and forcing a controlled air stream with known pollutant concentrations through it at a defined face velocity, following the similar testing concept of ASHRAE Standards 52.2 and 145.2. The purpose is to measure single-pass removal efficiency for each pollutant at the media level and to determine the adsorption capacity in a more accelerated manner. We will continuously introduce a target gas (for instance, H_2S at a fixed concentration) into the airflow and monitor the concentration downstream of the filter until breakthrough occurs (i.e., the downstream concentration rises to a specified fraction of the inlet). This yields the breakthrough curve and allows calculation of the total mass of pollutant captured per gram of sorbent (capacity) before saturation. We will perform such tests for selected key pollutants on samples from each sorbent-based filter in our device set. This helps rank materials by capacity

and informs expected maintenance/replacement intervals. The wind tunnel tests complement the chamber tests by providing data under idealized single-pass conditions (removal per pass, independent of room mixing effects).

Outputs of Task 3*:* We will obtain a rich dataset for the 30 devices, including: CADR values for H_2S, NO_2, and selected speciated VOCs; rates of any byproduct generation (e.g. µg/hr of ozone if produced); energy usage (W) at operational settings; qualitative notes on noise or usability; and filter media capacities/lifetimes. These results will allow us to identify the top-performing technologies for each pollutant and also highlight any devices that should be avoided due to poor performance or high emissions. The findings from Task 3 will directly inform which devices are selected for the field trial in Task 4. We anticipate selecting a subset of the highest-ranked options (likely one portable unit and one HVAC filter type) for deployment in homes. Task 3 results will be documented in the interim data report and the final report and will be used to answer research questions about lab vs. field performance gaps.

Task 4: Field Deployment and Community Field Study. In this task, we will implement the interventions in actual homes in the three communities, following a randomized controlled trial design to evaluate real-world effectiveness. Each of the 45 participant homes will be assigned to one of three groups: Control, PAC Intervention, or HVAC Filter Intervention (15 homes per group, distributed roughly equally across the three communities). Control homes will receive an indoor air device that addresses only particulate matter (for example, a HEPA air purifier with no activated carbon), effectively serving as a “placebo” for gas removal – this controls for any placebo effect or general improvements unrelated to gas filtration. PAC intervention homes will receive one of the top-performing portable air cleaners (from Task 3 results) that targets gas pollutants, and HVAC intervention homes will have their central HVAC system outfitted with a high-performing gas-phase filter. At each location (~15 homes), the deployment will be further divided into two to three batches (~5 to 8 homes per batch) in different 10-week periods, scheduled to coincide with historically high pollution or odor periods. We will collaborate with CARB to review the historical air quality trends in the three study sites and consult community partners to align deployment with peak episodes—ensuring that at least one batch captures peak gas issues. Besides, the design of rollout in batches enables efficient use of sampling equipment and allows timely engagement with households to troubleshoot and optimize device use. The design of the field study is illustrated below.

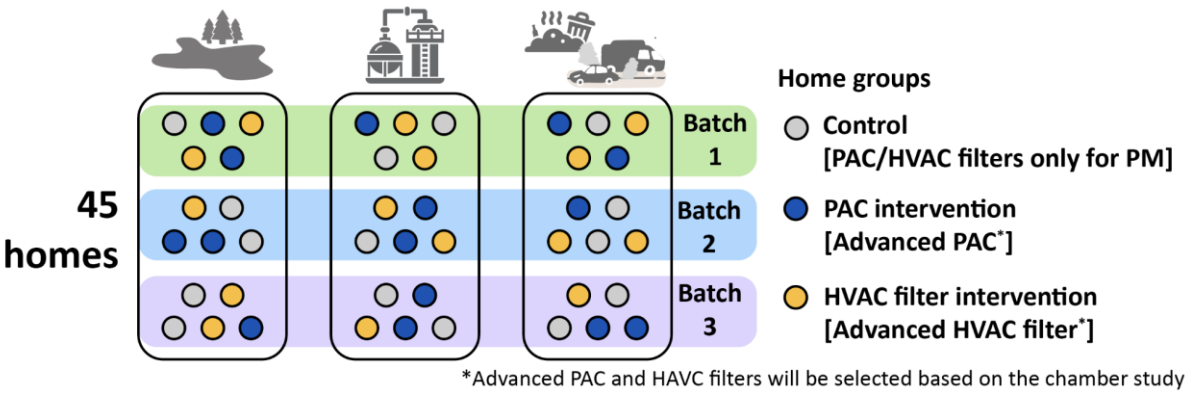


Figure 1. Schematic of the community field study design. 45 participating homes are randomized into three equal groups: Control (gray circles — receive PM-only filtration devices), PAC Intervention (blue circles — receive the top-performing PAC identified in Task 3), and HVAC Filter Intervention (gold circles — receive a top-performing gas-phase HVAC filter). Homes are enrolled in three batches to align deployments with seasonal or source conditions across the three study regions

The general study protocol per home is illustrated in Figure 2.

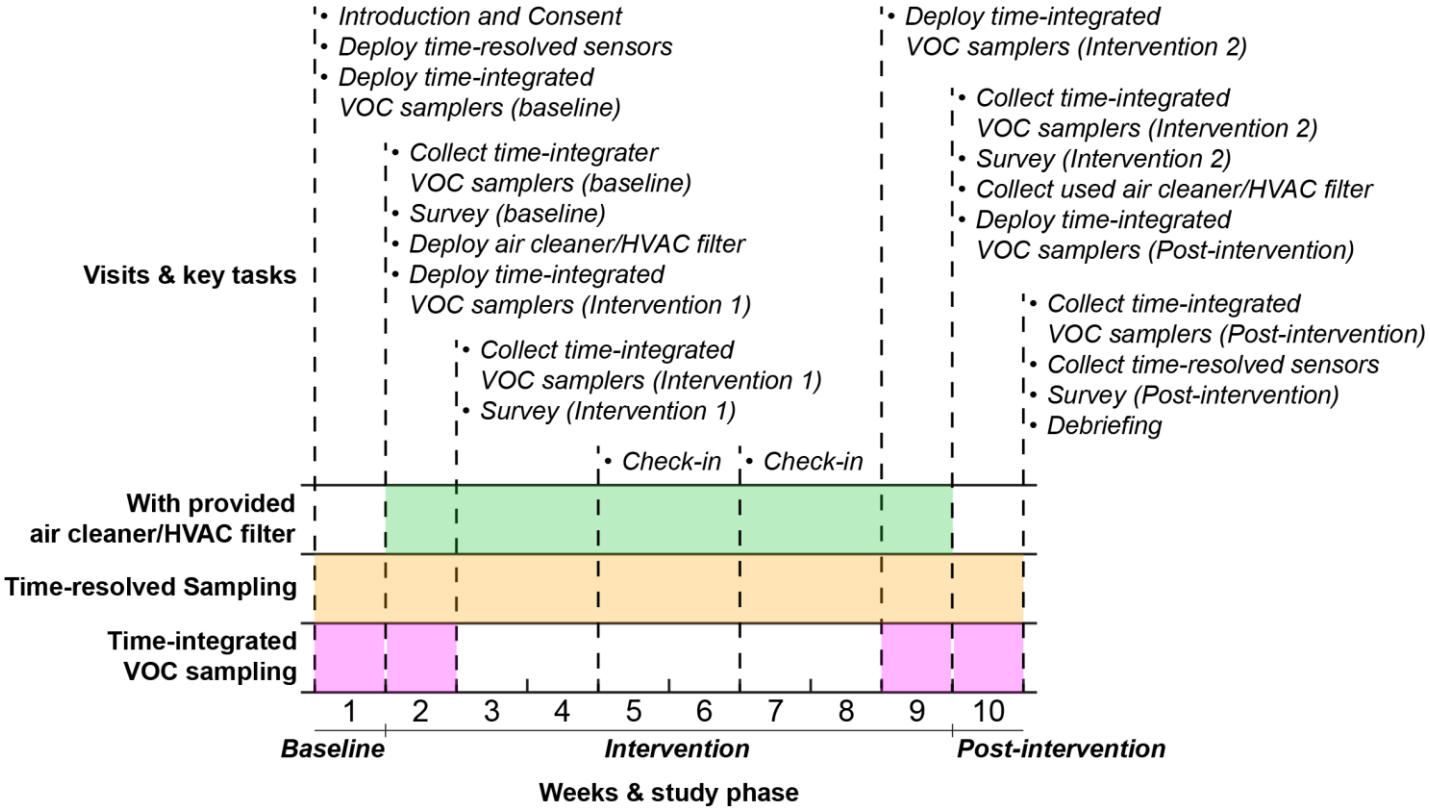


Figure 2. Tentative study schedule for each participating home.

Baseline Monitoring (1 week): Before any air cleaner is introduced, each home will be monitored for about 1 week to establish baseline indoor air quality and occupant experience. This involves placing our monitoring equipment in the home (described below) and instructing the household to operate their home as usual. No new filtration devices are in use during this period (aside from whatever they already normally use, which we will document). During the baseline, we will deploy the real-time NO_2, H_2S, and formaldehyde sensors, deploy and collect the first set of VOC samples, and administer a baseline survey about the home and residents (including any baseline odor concerns, self-reported health symptoms, etc.).

Intervention Period (8 weeks): We then deploy the assigned intervention. For PAC group homes, a portable gas-phase air cleaner will be installed (and any existing devices they have for air cleaning will be left in place, but we will ask them to use our provided device as the primary air cleaner). For HVAC filter group homes, we will install/replace the specialized filter in their furnace/AC. Households will be instructed in simple terms on how and when to operate the provided device. The intervention lasts 8 weeks, during which the monitoring continues uninterrupted. We will record the usage of PAC using smart plugs and HVAC by measuring the current using clip-on CT logger or monitoring the change of supply air temperature. Additionally, we will check in periodically (including an in-person or phone check mid-way) to ensure the sensors and equipment are functioning. We will deploy the time-integrated VOC samplers at the beginning and end of the first and last week. Occupants will also fill out brief surveys at the start and end of this period to capture their perceptions: e.g., “Are you noticing fewer odors?”, “Did you experience any changes in symptoms?”,

“Are you willing to buy this type of air cleaning device, and how much?”, “Is the device easy to use, or are there any problems (noise, etc.)?”.

Post-Intervention Monitoring (1 week): After 8 weeks, we will continue to monitor the homes for an additional 1 week without the intervention devices. Participants will be asked to not use the intervention devices or filters for 1 week. The aged devices and filters will be sent back to UC Berkeley to do the re-test, as mentioned in Task 3.1. For those participants in the PAC group who want to keep the device, we will ship it back after re-testing with the new filters. For the HVAC group, we will replace the used filters with new. This post-intervention period helps observe if pollutant levels or conditions rebound, and serves as another comparison to the baseline. We will collect time-integrated VOC samples at week 10, and a final survey will record any changes noticed once the device is removed.

Throughout all phases, environmental data collection in each home will include: continuous time-resolved measurements of NO_2, H_2S, and formaldehyde using calibrated electrochemical sensor nodes placed in the space where occupant stay most; continuous logging of temperature, relative humidity, and CO_2; integrated VOC sampling using passive sorbent badges deployed for 7-day intervals at four points: Week 1 (baseline), Week 2 (start of intervention), Week 9 (end of intervention), and Week 10 (post-intervention week) – these samples will be analyzed for a broad spectrum of VOCs (including specific toxic air contaminants of interest and odorants) by thermal desorption gas chromatograph mass spectrometry (GC-MS) to quantify any changes in indoor VOC concentrations attributable to the interventions. Additionally, we will collect data on device usage and energy (for PACs, we may use smart plugs or built-in logs to see how often and at what power the device ran). This will enable us to calculate actual operational costs and usage patterns.

Community field staff will visit each home at regular intervals (at least bi-weekly) to download data and address any equipment issues. They will also serve as a point of contact for participants to report problems or ask questions. If a participant wishes to withdraw or reports device malfunctions, our protocol will have contingencies (e.g., replace with a backup device, or drop the home data if necessary). We will also organize a mid-study community meeting (approximately at the halfway point of the field campaign) in each area to share preliminary observations and maintain engagement – residents can give feedback, and the team can reinforce proper device use or adjust strategies as needed. CARB staff will be invited to these meetings to observe and contribute, ensuring transparency and community trust.

By the conclusion of Task 4, we expect to have a complete dataset of indoor air quality measurements and occupant feedback from 45 homes over 10-week trials, with and without intervention. The field study will reveal how well the air cleaners perform in real homes: for instance, the percentage reduction in NO_2, H_2S, or speciated VOCs, any differences in performance across the three regions (which could indicate influence of climate, housing type, or source strength), and insights into maintenance needs (e.g. did any filters saturate within 8 weeks, as indicated by performance drop-off). It will also shed light on community acceptance – whether people found the devices helpful and are willing to use them, which is crucial for any recommendations we make.

Task 5: Data Analysis, Synthesis of Results, and Development of Recommendations. In this task, we will analyze the data collected from both the laboratory tests (Task 3) and the field study (Task 4) to draw conclusions and formulate guidance for CARB and the public. This task runs

concurrently with parts of Task 4 – we will begin data analysis as interim results become available – and intensifies after all data collection is complete.

Task 5.1: Laboratory Data Analysis – We will process the chamber test results to rank the tested technologies. For each device (or device class), we will tabulate: CADRs for each pollutant; any byproduct emission rates (e.g. mg of ozone produced per hour); the estimated filter lifetime or gas removal capacity (from breakthrough tests); noise levels and energy efficiency (CADR per Watt); and overall cost factors (purchase price plus projected annual filter replacements and electricity costs). We will produce comparative charts such as *CADR vs. cost* and *byproduct emissions vs. CADR* to visualize trade-offs. These analyses will identify the "top performers" for removing NO_2, for removing H_2S, and for VOC/odor control, as well as highlighting any devices that had unacceptable side effects (e.g., high ozone generation). Where possible, we will also compare our findings to any manufacturer specifications or claims to see if they hold true.

Task 5.2: Field Data Analysis – We will analyze the field measurements to evaluate effectiveness in homes. This includes calculating the reduction in pollutant concentrations: for each home, we can compare the baseline phase vs. intervention phase levels of NO_2, H_2S, formaldehyde, and individual VOCs. Because we have control homes, we will use statistical methods (e.g., differences-in-differences analysis or ANOVA) to distinguish real intervention effects from background temporal variation. We will also examine sensor time series to see if the intervention devices consistently maintained lower pollutant levels and how factors like door/window opening or stove use affected results. Another aspect is filter degradation: after the field trial, we will retrieve the used filters and PAC units and perform *post-use chamber tests* (as noted in Task 3A) to quantify any decline in performance after weeks of operation. This will tell us if, for example, an activated carbon filter's CADR dropped significantly after 2 months of use in a high-pollution home. Survey responses from occupants will be analyzed to gauge satisfaction (Did odors improve? Any noted health improvements like less frequent headaches?), ease of use, and any complaints (like noise or drafts).

Task 5.3: Cost-Effectiveness and Equity Analysis – We will combine the performance data with cost data to analyze the cost-effectiveness of the interventions. For each device or strategy, we will estimate the cost per unit pollutant removed (e.g., dollars per mg of VOC removed or per ppb reduction achieved) over a typical usage scenario. This accounts for initial cost, filter replacement frequency, and energy consumption. We will specifically look at scenarios relevant to low-income households: e.g., if a carbon filter panel needs replacing every 3 months at $30 each, can an average household afford this? We will model potential subsidy programs or bulk purchase programs and estimate their impact, for instance, how much funding would be needed to provide effective filters to households in an entire community for a year. This analysis will inform policy recommendations on incentive programs. We will also ensure to address equity implications: identifying if there are barriers for certain communities in adopting these solutions (such as lack of HVAC systems in older homes making portable units the only option, language barriers in understanding instructions, or cost). Our analysis will consider these factors so that recommendations are tailored to be inclusive and effective in practice.

Task 5.4: Synthesis into Guidance and Tools – A major deliverable of this project is a set of practical guidance materials that translate the scientific findings into user-friendly recommendations. Based on the rankings and analyses above, we will prepare: (a) A technology ranking and best-use guide – essentially a report section (or standalone document) that lists each technology category and its pros/cons, including effectiveness for each pollutant, typical costs, and maintenance needs. This will help CARB and the public quickly see which solutions are most effective and safe. (b) Use-

case “recipes” – we will identify a few common scenarios (wildfire smoke intrusion, living near a refinery or freeway, persistent sewer odors, etc.) and recommend the best combination of measures for each. (c) A concise decision flowchart or lookup table that a homeowner or building manager can use to choose an air cleaner: this might match pollutant problems to the appropriate device type and indicate expected cost. (d) Community outreach materials – as part of ensuring the research benefits are returned to communities, we will create plain-language, accessible summaries (e.g., a 2-to-4-page bilingual fact sheet and a one-page infographic) that distill the key findings and recommendations for the general public.

All the analyses and recommendations from Task 5 will be documented in the project reports (Progress Report, Draft Final Report, Final Report). We will highlight how the results answer the original research questions and how they can be applied in real-world policy and practice.

Task 6: Reporting and Dissemination. This task covers all ongoing project management and the required reporting and outreach activities to ensure the project stays on track and the results are shared effectively.

Task 6.1: Progress Reports – The team will prepare quarterly progress reports throughout the project period, documenting the work completed each period, any problems encountered, and upcoming plans. Each progress report will include a brief summary of the project status, an account of tasks completed or in progress, any deviations from the schedule with explanations, and any interim findings of interest. These reports will be submitted to CARB alongside each quarterly invoice, per contract requirements, and discussed in quarterly meetings. Progress reports ensure transparency and allow CARB to provide feedback or guidance during the project.

Task 6.2: Draft Final Report – Nine months before the project end date, the research team will produce a comprehensive Draft Final Report detailing the entire study. The report will include an abstract, introduction/background (including the statement of significance and literature review findings), a methods section describing the laboratory and field methodologies, results and analysis (with figures/tables summarizing key data), discussion of findings (including limitations and potential future research needs), and conclusions/recommendations. Per CARB requirements, the Draft Final Report will also include two special addendum sections: a Public Outreach Document (a one-page standalone summary in non-technical language highlighting the motivation, key findings, and recommendations for the general public) and an Equity Implications Section (a discussion of how the results inform understanding of impacts on disadvantaged communities and how the findings can support equitable air quality improvements). The Principal Investigator will review and approve the report, certifying that it meets quality standards, before transmitting it to CARB for review. We anticipate CARB and potentially external reviewers will provide comments on the draft.

Task 6.3: Final Report and Deliverables – The team will revise the Draft Final Report in response to CARB’s review comments and produce the Final Report. The Final Report will be an ADA-compliant document (formatted to meet Web Content Accessibility Guidelines 2.1 AA standards), suitable for public posting on the CARB website. It will incorporate all required elements (the one-page Public Outreach summary and the Equity Implications section, updated as needed) and will be fully proofread. Along with the written report, we will deliver all underlying data compilations (organized, cleaned datasets of chamber results, field measurements, survey responses, etc.) to CARB in an agreed-upon format, and a brief data dictionary describing the variables and any

processing that was applied. Before the end of the project, we will also conduct a Technical Seminar (Task 6.5) to present the study results.

Task 6.4: Technical Seminar and Outreach – The Principal Investigator and key researchers will present the findings of the project at a CARB research seminar. This seminar will likely be a 60–90 minute presentation at CARB's facilities in Sacramento or El Monte (or virtual webcast), open to CARB staff, air quality management districts, and the public. We will prepare presentation slides that are ADA-compliant and submit them in advance to CARB. The seminar will cover the project motivation, methods, key results, and recommendations, and include time for Q&A. We will also use this opportunity to disseminate the plain-language outreach materials (fact sheet, etc.) we developed, by providing copies or links to attendees. Beyond the CARB seminar, team members may present this work at conferences or community meetings and will coordinate with CARB's outreach staff to maximize the impact of the findings. Research outcomes and progress for the project will be presented at CBE Industry Advisory Board (IAB) meetings hosted every 6 months as indicated in the Project Schedule. Following the project presentations, recordings will be made available via the CBE YouTube page and advertised throughout CBE's website and newsletters. We will present the findings at a domestic conference in the related field, such as IAQVEC 2026 in Los Angeles, ASHRAE Annual or Winter conferences, and AAAR Annual conferences. All outreaches will properly acknowledge CARB's support and ensure that messages are consistent with CARB policy guidance.

Potential Challenges and Solutions: We recognize several potential challenges in this project and have planned mitigation strategies. One challenge is device selection and representativeness: the market of air cleaners is large, and new models appear frequently. To address this, our Task 1 review and engagement with CARB and community advisors will ensure we pick devices that are currently relevant and of high interest (including any emerging technologies). If a chosen device becomes unavailable (discontinued) during the project, we will select a close alternative. Another challenge is field study variability – indoor environments are complex, and occupant behavior could confound results (for example, a family might start heavy frying cooking during the "after" period, adding VOCs). We mitigate this by having a control group and by collecting detailed contextual data (surveys, CO_2 as a proxy for ventilation, etc.) to adjust for such factors in the analysis. Participant retention is also critical: households might drop out or not follow protocols. Our use of incentives, frequent communication through community partners, and designing the study to minimize inconvenience (e.g., mostly passive monitoring) will help maintain participation. In case of dropouts, we will have a waitlist of replacement homes ready. Data quality is another area: sensor drift or failures could occur. We will implement quality assurance by cross-calibrating sensors (for example, co-locating them in the chamber with reference instruments before and after deployment) and have backup instruments if one fails. If certain data are too noisy or lost, our relatively large sample size (45 homes) ensures the overall study integrity is maintained. The project's success will be measured by our ability to deliver robust data and clear findings despite these challenges. Benchmarks for success include: completing the planned 30 device tests and 45-home deployments within the schedule, collecting sufficient data for evaluating the lab and field effectiveness, and producing guidance that is well-received by CARB and community stakeholders. By anticipating potential problems and building in adaptive strategies, we are confident in achieving the project goals.

Meetings

Initial Meeting: Before commencing any research activities, the Principal Investigator and key project personnel will meet with the CARB Contract Project Manager (either in person or via videoconference) to discuss the overall project plan. This kickoff meeting will cover the detailed approach to each task, the project schedule and key milestones, any project staffing or coordination issues, and to resolve any outstanding questions so that work can begin smoothly. *(Deliverable: Meeting held by Month 1; see Deliverables table.)*

Progress Review Meetings: The Principal Investigator and appropriate team members will meet with the CARB Contract Project Manager at least quarterly (every three months) throughout the project. In these meetings (which may be teleconferences), we will present updates on progress for each task, provide preliminary results as available, and discuss any challenges encountered. The schedule of these meetings will be aligned with the submission of quarterly progress reports and invoices. These regular check-ins ensure that CARB is informed of interim findings and that any course corrections can be made with CARB's input.

Community Engagement Meetings: The project team will hold outreach meetings (town-halls, webinars, or workshop tables) in each community at project start and mid-study. Draft slides and handouts will be reviewed by Big Valley and CCEJN before public release; CARB staff will receive the same drafts for policy accuracy. CARB may attend any public meeting virtually or in person.

Technical Seminar: Toward the end of the project (prior to contract conclusion), the team will deliver a technical seminar at CARB. This seminar will be an opportunity to present the key results of the study directly to CARB staff, decision-makers, and the public (via webcast). The presentation will be coordinated with CARB's Research Division and will likely take place in Sacramento, unless otherwise arranged. All seminar presentation materials (PowerPoint slides, etc.) will be prepared in an ADA-compliant format (meeting WCAG 2.1 AA and Section 508 standards), as required for public dissemination. The seminar will allow CARB staff to ask questions and will facilitate knowledge transfer of the research findings for CARB's program use.

Data Management Plan

Data to be Collected: This project will generate several types of data: (1) **Laboratory experimental data** from chamber and wind tunnel tests (including time-resolved pollutant concentrations, calculated CADRs, breakthrough curves, device settings, etc.), (2) **Field monitoring data** from homes (time-series sensor readings for gases and environmental conditions, integrated VOC sample analysis results, device usage logs), (3) **Survey and observational data** (occupant responses to questionnaires, field logs of any noteworthy events or issues in each home), and (4) **Cost and meta-data** (device costs, maintenance records, and any ancillary notes on community context). In terms of volume, the sensor time-series data will likely be the largest across 45 homes and multiple weeks, but these are relatively small in size (text or CSV files). VOC laboratory analysis results will be a matrix of compounds by sample.

Data Handling and Storage: We will utilize a secure project database and file repository (such as a cloud-based data platform) to store all raw and processed data. Each type of data will have a standardized format: for example, continuous sensor data will be stored as CSV files with timestamps and sensor readings; VOC sample results will be in spreadsheets listing compound concentrations by sample ID; survey data will be in a coded spreadsheet with anonymized household IDs. We will maintain a master key that links household IDs to any personally identifiable

information (household address, participant contact info) in a separate secure. Access to survey data and participant information is limited only to those with a need to know for purposes of implementing or evaluating the research. Day-to-day, data will be collected by team members and community partners, then uploaded to the central repository. We will implement version control for datasets and regularly back up the data (at least weekly) to prevent loss.

Data Quality Assurance: Quality control steps will be taken at multiple stages. In the laboratory, instruments will be calibrated against known standards before and after test runs. Duplicate or blank samples will be included for VOC analyses to check for contamination or analytical drift. In the field, each sensor node will be factory-calibrated and cross-checked against reference measurements. Field staff will follow checklists when deploying equipment to ensure consistency (e.g., placement of sensors, start/stop times). Data cleaning procedures will be documented: for instance, we may need to remove obvious outliers or periods when a sensor malfunctioned (which will be identified via logs or diagnostic flags). Any such data exclusion or interpolation will be recorded in a log. We will use statistical software (such as R or Python scripts) to perform data reduction (e.g., averaging 5-min data to 1-hr, computing baseline vs. intervention differences) – these scripts will be saved and commented to allow review and replication. Additionally, the Principal Investigator or a senior data analyst will conduct periodic audits of the data (spot-checking raw vs. processed data) to ensure integrity.

Data Analysis and Interpretation: Data analysis will largely be conducted with statistical software (R, Python, or similar). For the lab data, analysis includes fitting exponential decay models for CADR. For field data, statistical models such as the mixed-effects model will be used to compare conditions. All analysis code will be retained and can be provided as supplementary material if needed. Interpretation of the data will occur in team meetings, where multiple researchers review the results to arrive at a consensus on findings and their significance. The Equity Implications Section of the report will specifically interpret data in terms of impacts on disadvantaged groups (e.g., did homes in the lowest-income bracket see similar improvements as others? Are there any indications that certain interventions work better in one community context versus another?).

Data Format and Sharing: The final datasets delivered to CARB will be in non-proprietary, machine-readable formats (CSV or Excel for tables, PDF or image for any figures). We will also provide a **data dictionary** describing each variable (units, any data processing done). Personal identifiers will be removed or coded. For example, each home will be identified by a code rather than address or name. CARB will receive all the needed data to reproduce the report results. We anticipate making much of the data public (except possibly data that could identify a location or participant) in an archived dataset to accompany the final report, so that other researchers or community groups can further use the information. The data management approach ensures that all findings are backed by well-organized evidence and that the results can be independently verified if needed.

Project Schedule

This project is planned to span 30 months (2.5 years), with tasks overlapping strategically to maintain efficiency. Below is an overview of the timeline with key milestones and meetings:

The project is expected to span 30 months from the contract start date. The anticipated timeline for each task is outlined below (in project months, where Month 1 is the start of the project):

- **Task 1: Literature Review** – Months 1–3. *Start immediately at project onset; complete by the end of Month 3.* (Deliverable: incorporated into Draft Report by Month 21.)

- **Task 2: Community Engagement & Recruitment** – Months 3–6 (with some ongoing engagement through Month 12). *Begin outreach in Month 3; training and deployment preparations by Month 5*; recruitment of 15 homes in the first batch by Month 5.

- **Task 3: Laboratory Evaluation** (Chamber & Wind Tunnel Testing) – Months 3–6. *Device procurement and setup in Months 3; execute testing from Months 3–6.* Lab tests for 30 devices concluded by the end of Month 6. Some follow-up re-testing of used devices occurs in Months 8–16 after the field phase.

- **Task 4: Field Deployment in Homes** (45 Homes) – Months 5–18. *Deploy in 2 or 3 batches, and* we allow flexibility to arrange study batches to capture the odor event and the high usage of the HVAC system (for the HVAC group), as indicated by the Gantt chart. Within each batch, we also allow the flexibility of starting the sampling in participating homes at minus and plus one week.

- **Task 5: Data Analysis & Recommendations** – Months 5–20. *Initial data analysis begins once lab data are in (Month 5-9) and continues as field data come in (Month 10–16); final analysis and synthesis from Months 18–20.* (By Month 9, preliminary lab results analysis complete; by Month 16, full integration of field and lab results; draft recommendations by Month 19 for the Draft Final Report.)

- **Task 6: Reporting & Dissemination** – Months 1–24 *Project management ongoing throughout.* Quarterly progress reports delivered by Months 3, 6, 9, … etc. Draft Final Report due by Month 22 (which is 9 months before project end). CARB review and revisions in Months 22–30. Final Report and data due by Month 30 (project end). Technical Seminar scheduled around Month 30.

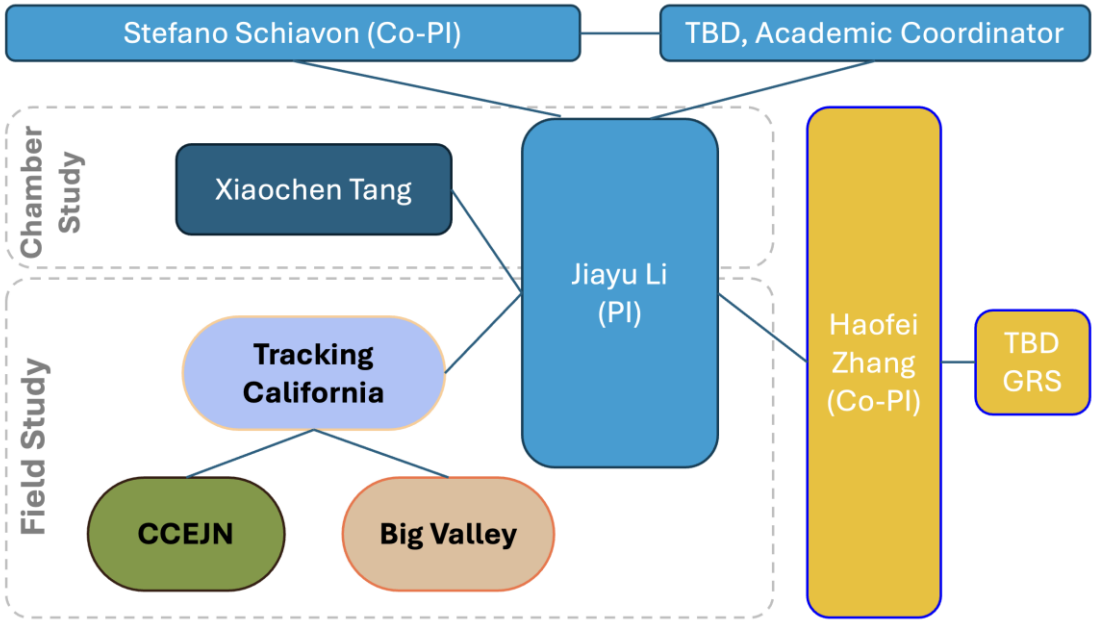
This schedule ensures a paced workflow: first 6 months focus on lab research and community setup, which allows more flexibility on field execution, analysis, and reporting to give buffer periods for unexpected delays. The project will meet all required deliverable deadlines (see Exhibit A1 – Deliverables for specific due dates).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Task 1 Literature Review																														
Task 2: Community Selection, Engagement, and Recruitment																														
2.1. Community Outreach																														
2.2. Participant Recruitment																														
2.3. Training and Deployment Preparations																														
Task 3: Laboratory Evaluation of Air Cleaning Technologies																														
3.1. Chamber Testing																														
3.2. Wind Tunnel Filter Testing																														
Task 4: Field Deployment and Community Field Study*																														
4.1. Batch 1																														
4.2. Batch 2																														
4.3. Batch 3 (TBD)																														
Task 5: Data Analysis, Synthesis of Results, and Development of Recommendations																														
5.1. Laboratory Data Analysis																														
5.2. Field Data Analysis																														
5.3. Cost-Effectiveness and Equity Analysis																														
5.4. Synthesis into Guidance and Tools																														
Task 6: Reporting and Dissemination																														
6.1. Progress Reports			p			p			p			p			p			p			p			p			p			p
6.2. Draft Final Report																						D								
6.3. Final Report and Deliverables																														F
6.4. Technical Seminar																														
Project management	m			m			m			m			m			m			m			m			m			m		X

m – meeting with ARB staff
p – progress report
X – deliverable submitted to CARB
D – draft final report to be submitted to CARB 9 months prior to project end date
F – final report submitted to CARB after comments have been addressed.
* The dark grey areas illustrate an example of study periods for three batches, while the light grey areas represent the flexibility in starting the batch to coincide with the odor period, the high usage of HVAC, and to avoid the holiday season.

Project Management Plan

The project team will be organized based on the following organizational chart:



The principal investigator (PI), Dr. Jiayu Li at UC Berkeley, leads laboratory evaluations, oversees the real-world field deployments, and serves as the primary point of contact with CARB. Working alongside him is an Academic Coordinator (to be named) who will support every workstream by

handling press releases, website updates, and subcontract coordination, thereby freeing the scientific team to focus on research tasks.

Two co-principal investigators will support and extend this leadership. Professor Stefano Schiavon at UC Berkeley will act as senior scientific advisor, providing strategic oversight of experimental design, resource allocation, and risk management across both the chamber and field studies. Assoc. Prof. Haofei Zhang at UC Riverside will lead the analytical chemistry vertical covering both chamber and field analysis: he supervises the graduate student researcher who conducts chemical analyses, maintains stringent quality-control logs, and delivers pollutant level datasets to Dr Li for synthesis and reporting.

Overall, this leadership structure balances day-to-day operational control (Li), senior scientific guidance (Schiavon), and specialized analytical expertise (Zhang).

The Chamber Study is managed by Dr Li in partnership with Dr Xiaochen Tang, who runs the PTR-MS and operates the full-scale test chamber. The Field Coordination stream is led by Tracking California, which directs statewide community coordination. Field study SOPs will be developed by researchers at UC Berkeley and UC Riverside and reviewed by Tracking California staff to create standard operating procedures and train community-based partners on sensor deployment and sampling, ensuring that data from Fresno, Kern, and Lake Counties enters the system in a consistent, high-quality format.

Field implementation is handled by two community partners. In the San Joaquin Valley, CCEJN (Central California Environmental Justice Network) recruits households, installs portable air cleaners or upgraded HVAC filters, and conducts bilingual outreach. In Lake County, the Big Valley Band of Pomo Indians Environmental Department plays the equivalent role, with a tribal liaison and field technician overseeing culturally appropriate recruitment, equipment installation, and participant support.

Facilities and Equipment: UC Berkeley's **Center for the Built Environment (CBE)** will provide the primary research facilities for this project. This includes the full-scale environmental test chamber described earlier, which is uniquely suited to testing air cleaning devices in controlled conditions. The chamber is housed in a dedicated laboratory with HVAC controls and instrumentation ports. CBE also has a **wind tunnel/duct setup** for filter testing and a suite of relevant analytical equipment (PTR-MS, particle counters, gas analyzers) that will be used in Task 3. Additional equipment such as the electronic sensor nodes for field measurements (NO_2, H_2S, etc.) are available through the research group or will be procured at project start – we have identified several suitable models based on prior projects. The community partners have office spaces and basic equipment in the target regions, and our budget includes provisions to equip them with any needed laptops or calibration kits so they can handle data collection tasks. All laboratory and field equipment needed for the project is either already available or will be acquired in the project's first month. No major facility renovations or animal/human laboratory facilities are needed beyond what is in place.

Human Subjects Considerations: The field portion of this project involves human subjects (residents in their homes), though primarily in an observational/interventional exposure study capacity (collecting environmental data and survey responses). As noted, we will obtain IRB approval from UC Berkeley's Office for Protection of Human Subjects before starting Task 4. Participant confidentiality and consent will be handled with utmost care – all participants will sign informed consent forms that have been approved by the IRB and (if required) by CARB. These

forms will clearly state the study procedures, risks (which are minimal, mostly just the presence of air monitoring devices and installation of air cleaners), and participants' rights (including the right to withdraw at any time). Personal data will be kept confidential, and any publications will only refer to aggregated or anonymized information. We do not anticipate involvement of any minors without parental consent or collection of any medical data beyond self-reported health symptoms in surveys. If any incidental findings occur (e.g., if we detect extremely high pollutant levels in a home), we have a protocol to inform the resident and assist in mitigation while maintaining safety.

Reference

ASHRAE, 2025. Standard 145.2-2025 Laboratory Test Method for Assessing the Performance of Gas-Phase Air-Cleaning Systems: Air-Cleaning Devices.

ASTM, 2025. WK81750 - new test method for chemical assessment of air cleaning technologies [WWW Document]. WK81750 - New Test Method Chem. Assess. Air Clean. Technol. URL https://www.astm.org (accessed 4.24.25).

Blue, B.W.C. of, May 10, C.H.R., 2021, 2021. California tribes call out degradation of clear lake. Calif. Health Rep. URL https://www.calhealthreport.org/2021/05/10/california-tribes-call-out-degradation-of-clear-lake/ (accessed 5.1.25).

CARB, 2018. South central fresno [WWW Document]. URL https://ww2.arb.ca.gov/capp/com/cip/south-central-fresno (accessed 5.1.25).

Chiu, C.H., Lozier, M., Bayleyegn, T., Tait, K., Barreau, T., Copan, L., Roisman, R., Jackson, R., Smorodinsky, S., Kreutzer, R., Yip, F., Wolkin, A., 2015. Geothermal gases – community experiences, perceptions and exposures in northern california. J. Environ. Health 78, 14–21.

Collins, D.B., Farmer, D.K., 2021. Unintended consequences of air cleaning chemistry. Environ. Sci. Technol. 55, 12172–12179. https://doi.org/10.1021/acs.est.1c02582

Jacobs, J.P., 2020. Anger over dirty air intensifies in calif.'s oil hub [WWW Document]. EE News Polit. URL https://www.eenews.net/articles/anger-over-dirty-air-intensifies-in-calif-s-oil-hub/ (accessed 4.22.25).

Li, Y.-W., Ma, W.-L., 2021. Photocatalytic oxidation technology for indoor air pollutants elimination: A review. Chemosphere 280, 130667. https://doi.org/10.1016/j.chemosphere.2021.130667

Link, M.F., Robertson, R., Claflin, M.S., Poppendieck, D., 2024. Quantification of byproduct formation from portable air cleaners using a proposed standard test method. Environ. Sci. Technol. 58, 7916–7923. https://doi.org/10.1021/acs.est.3c09331

Logue, J.M., McKone, T.E., Sherman, M.H., Singer, B.C., 2011. Hazard assessment of chemical air contaminants measured in residences. Indoor Air 21, 92–109. https://doi.org/10.1111/j.1600-0668.2010.00683.x

Mioni, C., Kudela, R., Baxa, D., 2011. Harmful cyanobacteria blooms and their toxins in clear lake and the sacramento-san joaquin delta (california), Report Prepared for Central Valley Regional Water Quality Control Board.

Morello-Frosch, R.A., Woodruff, T.J., Axelrad, D.A., Caldwell, J.C., 2000. Air toxics and health risks in california: The public health implications of outdoor concentrations. Risk Anal. 20, 273–292. https://doi.org/10.1111/0272-4332.202026

Pastor Jr., M., Morello-Frosch, R., Sadd, J.L., 2006. Breathless: Schools, air toxics, and environmental justice in california. Policy Stud. J. 34, 337–362. https://doi.org/10.1111/j.1541-0072.2006.00176.x

Pei, J., Zhang, J., 2010. Modeling of sorbent-based gas filters: Development, verification and experimental validation. Build. Simul. 3, 75–86. https://doi.org/10.1007/s12273-010-0309-4

Pei, J., Zhang, J.S., 2011. On the performance and mechanisms of formaldehyde removal by chemi-sorbents. Chem. Eng. J. 167, 59–66. https://doi.org/10.1016/j.cej.2010.11.106

Wang, P., Liu, J., Wang, C., Zhang, Z., Li, J., 2022. A holistic performance assessment of duct-type electrostatic precipitators. J. Clean. Prod. 357, 131997. https://doi.org/10.1016/j.jclepro.2022.131997

Ye, Q., Krechmer, J.E., Shutter, J.D., Barber, V.P., Li, Y., Helstrom, E., Franco, L.J., Cox, J.L., Hrdina, A.I.H., Goss, M.B., Tahsini, N., Canagaratna, M., Keutsch, F.N., Kroll, J.H., 2021. Real-time laboratory measurements of VOC emissions, removal rates, and byproduct formation from consumer-grade

oxidation-based air cleaners. Environ. Sci. Technol. Lett. 8, 1020–1025. https://doi.org/10.1021/acs.estlett.1c00773

EXHIBIT A1

DELIVERABLES

List all items that will be delivered to the State under the proposed Scope of Work. Include all reports, including draft reports for State review, and any other Deliverables, if requested by the State and agreed to by the Parties.

If use of any Deliverable is restricted or is anticipated to contain preexisting Intellectual Property with any restricted use, it will be clearly identified in Exhibit A4, Use of Preexisting Intellectual Property & Data.

Unless otherwise directed by the State, the University Principal Investigator shall submit all deliverables to State Contract Project Manager, identified in Exhibit A3, Authorized Representatives.

Deliverable	Description	Due Date
Racial equity/implicit bias training	The Principal Investigator and key personnel must demonstrate that they have taken, or will take, cultural competency training, implicit bias training, or racial equity training, whichever is administered at their institution. Training certificates or certificates of completion completed within one (1) year prior to the agreement start date will be accepted. If the training has not been completed within one (1) year prior to the agreement start date, then the Principal Investigator and key personnel must demonstrate that they have scheduled the training within 30 days of the agreement start date and shall complete the training within 90 days of the agreement start date.	Within 90 days of the agreement start date.
Initial Meeting	Principal Investigator and key personnel will meet with CARB Contract Project Manager and other staff to discuss the overall plan, details of performing the tasks, project schedule, items related to personnel or changes in personnel, and any issues that may need to be resolved before work can begin.	Month 1
Progress Reports & Meetings	Quarterly progress reports and meetings throughout the agreement term, to coincide with work completed in quarterly invoices.	Quarterly
Draft Final Report	Draft version of the Final Report detailing the purpose and scope of the work undertaken, the work performed, the results obtained and conclusions, and a Public Outreach Document and an Equity Implications Section. The Draft Final Report shall be copy-edited before being sent to CARB for review and the Principal Investigator shall attest that the Final Report has been reviewed and approved. The Draft Final Report must be submitted in accordance with the requirements outlined in Exhibit A1, Section 2 – Research Final Report Format.	Nine (9) months prior to the agreement end date.
Data	Data compilations first produced in the performance of this Agreement by the Principal investigator or the University's project personnel.	Two (2) weeks prior to agreement end date.

Technical Seminar	Presentation of the results of the project to CARB staff and a possible webcast at a seminar at CARB facilities in Sacramento or El Monte. The Technical Seminar slides shall be submitted in an ADA compliant format. CARB's standard for ADA compliance requires that the submitted document adhere to WCAG 2.1 AA (https://www.w3.org/TR/WCAG21/) and Federal Section 508 (https://www.section508.gov/).	On or before agreement end date.
The following Deliverables are subject to paragraph 19. Copyrights, paragraph B of Exhibit C		
Final Report	Written record of the project and its results. The Final Report must be submitted in accordance with the requirements outlined in Exhibit A1, Section 2 – Research Final Report Format.	Two (2) weeks prior to agreement end date.

1. Reports and Data Compilations

A. With respect to each invoice period University shall submit, to the CARB Contract Project Manager, one (1) electronic copy of the progress report. When emailing the progress report, the "subject line" should state the contract number and the billing period. Each progress report must accompany a related invoice covering the same billing period. Each progress report will begin with the following disclaimer:

> *The statements and conclusions in this report are those of the University and not necessarily those of the California Air Resources Board. The mention of commercial products, their source, or their use in connection with material reported herein is not to be construed as actual or implied endorsement of such products*.

B. Each progress report will also include:

1. A brief summary of the status of the project, including whether the project is on schedule. If the project is behind schedule, the progress report must contain an explanation of reasons and how the University plans to resume the schedule.

2. A brief narrative account of project tasks completed or partially completed since the last progress report.

3. A brief discussion of problems encountered during the reporting period and how they were or are proposed to be resolved.

4. A brief discussion of work planned, by project task, before the next progress report. and

5. A graph or table showing percent of work completion for each task.

C. Nine (9) months prior to Agreement expiration date, University will deliver to CARB an electronic copy of the draft final report in both PDF and Microsoft Word formats. The draft final report will conform to Exhibit A1, Section 2 – Research Final Report

Format.

D. Within forty-five (45) days of receipt of CARB's comments, University will deliver to CARB's Contract Project Manager an electronic copy of the final report incorporating all reasonable alterations and additions. Within two (2) weeks of receipt of the revised report, CARB will verify that all CARB comments have been addressed. Upon acceptance of the amended final report approved by CARB in accordance to Exhibit A1, Section 2 – Research Final Report Format, University will within two (2) weeks, deliver to CARB an electronic copy of the final report in both PDF and Microsoft Word formats.

E. As specified in Exhibit A1, Section 2, Final Report will be submitted in an Americans with Disabilities Act compliant Format.

F. Together with the final report, University will deliver a set of all data compilations as specified in Exhibit A1 – Schedule of Deliverables.

G. University's obligation under this Agreement shall be deemed discharged only upon submittal to CARB of an acceptable final report in accordance to Exhibit A1, Section 2 – Research Final Report Format, all required data compilations, and any other project deliverables.

2. Research Final Report Format

The research contract Final Report (Report) is as important to the contract as the research itself. The Report is a record of the project and its results and is used in several ways. Therefore, the Report must be well organized and contain certain specific information. The CARB's Research Screening Committee (RSC) reviews all draft final reports, paying special attention to the Abstract and Executive Summary. If the RSC finds that the Report does not fulfill the requirements stated in this Exhibit, the RSC may not recommend release, and final payment for the work completed may be withheld. This Exhibit outlines the requirements that must be met when producing the Report.

Note: In partial fulfillment of the Final Report requirements, the Contractor shall submit a copy of the Report in PDF format and in a word-processing format, preferably in Word – Version 6.0 or later. The electronic copy file name shall contain the CARB contract number, the words "Final Report", and the date the report was submitted.

Accessibility. Contractor must ensure that the Final Report complies with Web Content Accessibility Guidelines 2.0, levels A and AA, and otherwise meets the accessibility requirements set forth in California Government Code Sections 7405 and 11135, Section 202 of the federal Americans with Disabilities Act (42 U.S.C. § 12132), and Section 508 of the federal Rehabilitation Act (29 U.S.C. § 794d) and the regulations promulgated thereunder (36 C.F.R. Parts 1193 and 1194) (collectively, the "Accessibility Requirements"). For any report provided in PDF format, Contractor shall also provide an electronic version in the original electronic format (for example, Microsoft Word or Adobe InDesign). CARB may request documentation from the Contractor of compliance with the Accessibility Requirements and may perform testing to verify compliance. Contractor must bring into compliance, at no cost to CARB, any report by Contractor or its subcontractors not meeting the Accessibility

Requirements. If Contractor fails to bring its or its subcontractors' report into compliance with the Accessibility Requirements within five (5) business days of written notice from CARB, or within the time frame specified by CARB in its notice, Contractor will be responsible for all costs incurred by CARB in bringing Contractor's or its subcontractors' report into compliance with the Accessibility Requirements. Contractor agrees to respond to and resolve any complaint brought to its attention regarding accessibility of deliverables provided under this Contract for a period of one year following delivery of the final deliverable under this Contract.

Deviations from the Accessibility Requirements are permitted only by written consent by CARB.

Watermark. Each page of the draft Report must include a watermark stating "DRAFT." The revised report should not include any watermarks.

Title. The title of the Report should exactly duplicate the title of the contract. However, minor changes to the title may be approved provided the new title does not deviate from the old title. These minor changes must be approved in writing by the contract manager. Significant changes to the title would require a formal amendment.

Page size. All pages should be of standard size (8 ½" x 11") to allow for photo-reproduction.

Corporate identification. Do not include corporate identification on any page of the Final Report, except the title page.

Unit notation. Measurements in the Reports should be expressed in metric units. However, for the convenience of engineers and other scientists accustomed to using the British system, values may be given in British units as well in parentheses after the value in metric units. The expression of measurements in both systems is especially encouraged for engineering reports.

Section order. The Report should contain the following sections, in the order listed below:

Title page
Disclaimer
Acknowledgment (1)
Acknowledgment (2)
Table of Contents
List of Figures
List of Tables
Abstract
Public Outreach Document
Executive Summary
Equity Implications Section
Body of Report
References
List of inventions reported and copyrighted materials produced
Glossary of Terms, Abbreviations, and Symbols
Appendices

Page numbering. Beginning with the body of the Report, pages shall be numbered

consecutively beginning with “1”, including all appendices and attachments. Pages preceding the body of the Report shall be numbered consecutively, in ascending order, with small Roman numerals.

Title page. The title page should include, at a minimum, the contract number, contract title, name of the principal investigator, contractor organization, date, and this statement: "Prepared for the California Air Resources Board and the California Environmental Protection Agency"

Disclaimer. A page dedicated to this statement must follow the Title Page:

> The statements and conclusions in this Report are those of the contractor and not necessarily those of the California Air Resources Board. The mention of commercial products, their source, or their use in connection with material reported herein is not to be construed as actual or implied endorsement of such products.

Acknowledgment (1). Only this section should contain acknowledgments of key personnel and organizations who were associated with the project. The last paragraph of the acknowledgments must read as follows:

> This Report was submitted in fulfillment of [CARB contract number and project title] by [contractor organization] under the [partial] sponsorship of the California Air Resources Board. Work was completed as of [date].

Acknowledgment (2). Health reports should include an acknowledgment to the late Dr. Friedman. Reports should include the following paragraph:

> This project is funded under the CARB’s Dr. William F. Friedman Health Research Program. During Dr. Friedman’s tenure on the Board, he played a major role in guiding CARB’s health research program. His commitment to the citizens of California was evident through his personal and professional interest in the Board’s health research, especially in studies related to children’s health. The Board is sincerely grateful for all of Dr. Friedman’s personal and professional contributions to the State of California.

Attestation. A page dedicated to this attestation statement must follow the Acknowledgement(s). The Principal Investigator (PI) must digitally sign below the following statement:

> The Final Report for CARB Agreement No. [contract number] titled “[Enter project title]” has been copy-edited for grammar, style, and format and is reviewed and approved by the Principal Investigator (PI), [title and name of PI] of [Contractor Name]. The signature below attests that the PI has completed a thorough review of this Final Report and approves it for submission to the California Air Resources Board.
>
> PI Signature
> Date

Table of Contents. This should list all the sections, chapters, and appendices, together with their page numbers. Check for completeness and correct reference to pages in the Report.

List of Figures. This list is optional if there are fewer than five illustrations.

List of Tables. This list is optional if there are fewer than five tables.

Abstract. The abstract should tell the reader, in nontechnical terms, the purpose and scope of the work undertaken, describe the work performed, and present the results obtained and conclusions. The purpose of the abstract is to provide the reader with useful information and a means of determining whether the complete document should be obtained for study. The length of the abstract should be no more than about 200 words. Only those concepts that are addressed in the executive summary should be included in the abstract.

Example of an abstract:

A recently developed ground-based instrument, employing light detecting and ranging (lidar) technology, was evaluated, and found to accurately measure ozone concentrations at altitudes of up to 3,000 meters. The novel approach used in this study provides true vertical distributions of ozone concentrations aloft and better temporal coverage of these distributions than other, more common methods, such as those using aircraft and ozonesonde (balloon) techniques. The ozone and aerosol measurements from this study, in conjunction with temperature and wind measurements, will provide a better characterization of atmospheric conditions aloft and the processes involved in the formation of unhealthful ozone concentrations than can be achieved with traditional ground-based monitors.

Public Outreach Document. The public outreach document is a one-page document that will be widely used to communicate, in clear and direct terms, the key research findings from the study to the public. CARB will be translating the document into other languages. This document must adhere to the following guidelines:

- Single space, limited to one-page or about 500 words.
- Use narrative form and active voice.
- Incorporate a graphic that it is easy to interpret and captures the results' central message.
- Avoid jargon and technical terms. Use a style and vocabulary level comparable to that of sixth grade reading level.
- The document should contain a title and the following five sections: Issue/s, Main Question, Key Research Findings, Conclusion/s, and More Information. Guidance on how to write these sections is described below.

  TITLE: Adopt a short, non-technical title to make the topic clear and concise. The title will likely differ from the original title of the contract.

  ISSUE/S: In one to two paragraphs, describe why the project was needed. In this section, identify the problem leading to this study and what the study was set to

accomplish to help address the problem. Reference any history that is relevant such as a regulation, legislation, program, law, or other. Without going into detail and disclosing the research findings, mention the methods used in the study and how it informed the results.

MAIN QUESTION: Present a concise central research question driving this project.

KEY RESEARCH FINDING/S: This section covers the key research findings. List key points and or findings.

CONCLUSION/S: In one to two paragraphs, discuss how the results could be used. Mention its relevance to policies, rules, regulations, legislations, or CARB programs. Include suggestions for next steps, additional research, or other actions.

MORE INFORMATION: In two to three short sentences provide specifics about the study. This section should include the full title of the study, sponsor, authors, and where the full report can be found (the final report will be posted on the CARB website). In addition to a direct contact to gain more information (author and CARB contract manager).

Executive Summary. The function of the executive summary is to inform the reader about the important aspects of the work that was done, permitting the reader to understand the research without reading the entire Report. It should state the objectives of the research and briefly describe the experimental methodology[ies] used, results, conclusions, and recommendations for further study. All of the concepts brought out in the abstract should be expanded upon in the Executive Summary. Conversely, the Executive Summary should not contain concepts that are not expanded upon in the body of the Report.

The Executive Summary will be used in several applications as written; therefore, please observe the style considerations discussed below.

Limit the Executive Summary to two pages, single spaced.

Use narrative form. Use a style and vocabulary level accessible to the general audience. Assume the audience is being exposed the subject for the first time.

Do not list contract tasks in lieu of discussing the methodology. Discuss the results rather than listing them.

Avoid jargon.

Define technical terms.

Use passive voice if active voice is awkward.

Avoid the temptation to lump separate topics together in one sentence to cut down on

length.

The Executive Summary should contain four sections: Background, Objectives and Methods, Results, and Conclusions, described below.

THE BACKGROUND SECTION. For the Background, provide a one-paragraph discussion of the reasons the research was needed. Relate the research to the Board's regulatory functions, such as establishing ambient air quality standards for the protection of human health, crops, and ecosystems; the improvement and updating of emissions inventories; and the development of air pollution control strategies.

THE OBJECTIVES AND METHODS SECTION. At the beginning of the Objectives and Methods section, state the research objectives as described in the contract. Include a short, one or two sentences, overview of what was done in general for this research.

The methodology should be described in general, nontechnical terms, unless the purpose of the research was to develop a new methodology or demonstrate a new apparatus or technique. Even in those cases, technical aspects of the methodology should be kept to the minimum necessary for understanding the project. Use terminology with which the reader is likely to be familiar. If it is necessary to use technical terms, define them. Details, such as names of manufacturers and statistical analysis techniques, should be omitted.

Specify when and where the study was performed if it is important in interpreting the results. The findings should not be mentioned in the Objectives and Methods section.

THE RESULTS SECTION. The Results section should be a single paragraph in which the main findings are cited, and their significance briefly discussed. The results should be presented as a narrative, not a list. This section must include a discussion of the implications of the work for the Board's relevant regulatory programs.

THE CONCLUSIONS SECTION. The Conclusions section should be a single short paragraph in which the results are related to the background, objectives, and methods. Again, this should be presented as a narrative rather than a list. Include a short discussion of recommendations for further study, adhering to the guidelines for the Recommendations section in the body of the Report.

Equity Implication Section. The equity implications section should summarize how the research results inform disparate impacts of policies, regulations, or programs on priority communities.[5] This section should summarize how sociodemographic

[5] Priority communities here encompasses various terms CARB uses such as priority populations[2], communities of concern[3], protected classes[4], or disadvantaged communities[5].
[2] Priority Populations — California Climate Investments

factors were examined in this research. Given the data used or collected, which populations are excluded or overrepresented? How were relevant communities engaged in the research effort and/or how were existing data gaps identified and ground-truthed during the research project? If ground-truthed data were found to not accurately reflect the lived experiences of community members, what future research projects could address this disconnect. The research results should inform existing or future CARB programs and the equity implications section should discuss how the research results may inform programs to close disparities in health outcomes, pollutant exposure or climate adaptation, etc., for priority communities. This section should be limited to a maximum of two (2) pages, single spaced and shall include the following sections.

HISTORICAL ANALYSIS. Provide an overview of the inequities and disparities observed in the existing data or data gathered during the research and how it ties to historic policies. For example, what is the root-cause of the disparity being experienced by the community or population central to this research?

MATERIALS AND METHODS. Describe how this research project examines racial equity. Some methods can include but are not limited to: examining the potential for existing data to address racial inequalities, ground-truthing existing data, engaging priority communities, assessments for racial and ethnic subgroups in the development of data and approaches, identifying data gaps and filling those gaps.

RESULTS AND DISCUSSION. Describe how the results improve our understanding of the equity issues identified or interventions to address those inequalities.

Body of Report. The body of the Report should contain the details of the research, divided into the following sections:[6]

INTRODUCTION. Clearly identify the scope and purpose of the project. Provide a general background of the project. Explicitly state the assumptions of the study.

Clearly describe the hypothesis or problem the research was designed to address. Discuss previous related work and provide a brief review of the relevant literature on the topic.

MATERIALS AND METHODS. Describe the various phases of the project, the theoretical approach to the solution of the problem being addressed, and limitations to the work. Describe the design and construction phases of the project, materials,

[3] Referenced from the California Public Utilities Commission Environmental and Social Justice Plan an effort resulting from California's Capitol Collaborative on Race & Equity.
[4] Protected Classes | California State Senate
[5] SB 535 Disadvantaged Communities ; California Climate Investments to Benefit Disadvantaged Communities | CalEPA; CalEnviroScreen 4.0 | OEHHA

[6] Note that if the research employs multiple distinct methods, analyses, etc., the final report can include separate materials/methods, results, and discussion sections to allow for coherent discussion of each set of analyses and findings. However, the executive summary and conclusions sections should synthesize the collective findings of the entire study.

equipment, instrumentation, and methodology.

Describe quality assurance and quality control procedures used. Describe the experimental or evaluation phase of the project.

RESULTS. Present the results in an orderly and coherent sequence. Describe statistical procedures used and their assumptions. Discuss information presented in tables, figures, and graphs. The titles and heading of tables, graphs, and figures, should be understandable without reference to the text. Include all necessary explanatory footnotes. Clearly indicate the measurement units used.

DISCUSSION. Interpret the data in the context of the original hypothesis or problem. Does the data support the hypothesis or provide solutions to the research problem? If appropriate, discuss how the results compare to data from similar or related studies. What are the implications of the findings?

Identify innovations or development of new techniques or processes. If appropriate, discuss cost projections and economic analyses.

SUMMARY AND CONCLUSIONS. This is the most important part of the Report because it is the section that will probably be read most frequently. This section should begin with a clear, concise statement of what, why, and how the project was done. Major results and conclusions of the study should then be presented, using clear, concise statements. Make sure the conclusions reached are fully supported by the results of the study. Do not overstate or overinterpret the results. It may be useful to itemize primary results and conclusions. A simple table or graph may be used to illustrate.

RECOMMENDATIONS. Use clear, concise statements to recommend (if appropriate) future research that is a reasonable progression of the study and can be supported by the results and discussion.

References. Use a consistent style to fully cite work referenced throughout the Report and references to closely related work, background material, and publications that offer additional information on aspects of the work. Please list these together in a separate section, following the body of the Report. If the Report is lengthy, you may list the references at the end of each chapter.

List of inventions reported and publications produced. If any inventions have been reported, or publications or pending publications have been produced as a result of the project, the titles, authors, journals or magazines, and identifying numbers that will assist in locating such information should be included in this section.

Glossary of terms, abbreviations, and symbols. When more than five of these items are used in the text of the Report, prepare a complete listing with explanations and definitions. It is expected that every abbreviation and symbol will be written out at its first appearance in the Report, with the abbreviation or symbol following in parentheses [i.e., carbon dioxide (CO2)]. Symbols listed in table and figure legends need not be listed in the Glossary.

Appendices. Related or additional material that is too bulky or detailed to include within the discussion portion of the Report shall be placed in appendices. If a Report has only one appendix, it should be entitled "APPENDIX". If a Report has more than one appendix, each should be designated with a capital letter (APPENDIX A, APPENDIX B). If the appendices are too large for inclusion in the Report, they should be collated, following the binding requirements for the Report, as a separate document.

The contract manager will determine whether appendices are to be included in the Report or treated separately. Page numbers of appendices included in the Report should continue the page numbering of the Report body. Pages of separated appendices should be numbered consecutively, beginning at “1”.

3. Other Deliverables

A. Contractor must ensure that all products and services submitted, uploaded, or otherwise provided by the Contractor and/or its subcontractors under this Agreement, including but not limited to data, software, plans, drawings, specifications, reports, operating manuals, notes, and other written or graphic work prepared in the course of performance of this Contract (collectively, the “Work”), comply with Web Content Accessibility Guidelines 2.0, levels A and AA, and otherwise meet the accessibility requirements set forth in California Government Code Sections 7405 and 11135, Section 202 of the federal Americans with Disabilities Act (42 U.S.C. § 12132), and Section 508 of the federal Rehabilitation Act (29 U.S.C. § 794d) and the regulations promulgated thereunder (36 C.F.R. Parts 1193 and 1194) (collectively, the “Accessibility Requirements”). For any Work provided in PDF format, Contractor shall also provide an electronic version in the original electronic format (for example, Microsoft Word or Adobe InDesign). CARB may request documentation from the Contractor of compliance with the Accessibility Requirements and may perform testing to verify compliance. Contractor must bring into compliance, at no cost to CARB, any Work by Contractor or its subcontractors not meeting the Accessibility Requirements. If Contractor fails to bring its or its subcontractors’ Work into compliance with the Accessibility Requirements within five (5) business days of written notice from CARB, or within the time frame specified by CARB in its notice, Contractor will be responsible for all costs incurred by CARB in bringing Contractor’s or its subcontractors’ Work into compliance with the Accessibility Requirements. Contractor agrees to respond to and resolve any complaint brought to its attention regarding accessibility of deliverables provided under this Contract for a period of one year following delivery of the final deliverable under this Contract.

   Deviations from the Accessibility Requirements are permitted only by written consent by CARB.

EXHIBIT A2

KEY PERSONNEL

List Key Personnel as defined in the Agreement starting with the PI, by last name, first name followed by Co-PIs. Then list all other Key Personnel in alphabetical order by last name. For each individual listed include his/her name, institutional affiliation, and role on the proposed project. Use additional consecutively numbered pages as necessary.

Last Name, First Name	**Institutional Affiliation**	**Role on Project**
Principal Investigator (PI):		
Li, Jiayu	*University of California, Berkeley*	Chamber & field study lead, CARB liaison
Co-PI(s) – if applicable:		
Schiavon, Stefano	*University of California, Berkeley*	Project strategic oversight and scientific advisor
Zhang, Haofei	*University of California, Riverside*	Analytical chemistry lead
Other Key Personnel:		
Tang, Xiaochen	*University of California, Berkeley (MLA from Lawrence Berkeley National Laboratory)*	PTR-MS & chamber testing
TBD, Academic Coordinator	*University of California, Berkeley*	Communications & outreach coordinator
TBD, *GSR*	*University of California, Riverside*	Sample analysis & statistics
Wong, Michelle C	Tracking California	Community coordination & management
Martinez, Nayamin	Central California Environmental Justice Network	Community liaison – Fresno/Kern & field support
Ryan, Sarah	Big Valley Band of Pomo Indians	Tribal community liaison & field support

EXHIBIT A3

AUTHORIZED REPRESENTATIVES

The following individuals are the authorized representatives for the State and the University under this Agreement. Any official Notices issued under the terms of this Agreement shall be addressed to the Authorized Official identified below, unless otherwise identified in the Agreement.

State Agency Contacts	**University Contacts**
Agency Name: **CARB**	University Name: The Regents of the University of California, on behalf of its Berkeley campus (UCB)
Contract Project Manager (Technical)	***Principal Investigator (PI)***
Name: Address: Research Division 1001 I Street, 5th Floor Sacramento, CA 95814 Telephone: (916) Email: @arb.ca.gov	Name: Jiayu Li Address: 390 Wurster Hall #1839, Berkeley CA 94720-1839 Telephone: +1 (510) 345-7542 Email: Jiayu.li@berkeley.edu Designees to certify invoices under Section 14 of Exhibit C on behalf of PI: 1. N/A

Authorized Official (contract officer) Name: Alice Kindarara, Branch Chief Address: Acquisitions Branch 1001 I Street, 20th Floor Sacramento, CA 95814 alice.kindarara@arb.ca.gov ***Send notices to (if different):*** Name: Address: Research Division 1001 I Street, 7th Floor Sacramento, CA 95814 Telephone: (916) Email: @arb.ca.gov	***Authorized Official*** Name: Sabina Gafarova Assistant Director Address: Sponsored Projects Office 1608 Fourth Street, Suite 220 Berkeley, CA 94710-1749 Telephone: 510-642-0120 Fax: 510-642-8236 Email: spoawards@berkeley.edu ***Send notices to (if different):*** Name: Sabina Gafarova Assistant Director Address: Sponsored Projects Office 1608 Fourth Street, Suite 220 Berkeley, CA 94710-1749 Telephone: 510-642-0120 Email: spoawards@berkeley.edu
Administrative Contact Name: Address: Research Division 1001 I Street, 7th Floor Sacramento, CA 95814 Telephone: (916) Email: @arb.ca.gov	***Administrative Contact*** Name: Angela Brito Baldwin Principal Research Administrator Address: ERSO Berkeley Regional Services Telephone: N/A Fax: N/A Email: angelabrito@berkeley.edu

Financial Contact/Accounting	***Authorized Financial Contact/Invoicing/Remittance***
Name: Accounts Payable Address: P.O. Box 1436 Sacramento, CA 95814 Email: AccountsPayable@arb.ca.gov **Send courtesy copy to:** rd.invoices@arb.ca.gov	Name: Beata Najman Director Address:Contracts & Grants Accounting 2195 Hearst Ave, Room 130 Berkeley, CA 94720-1108 Telephone: 510-642-1400 Fax: 510-643-7628 Email: cgaawards@berkeley.edu Designees for invoice certification in accordance with Section 14 of Exhibit C on behalf of the Financial Contact: 1. N/A

EXHIBIT A4

USE OF INTELLECTUAL PROPERTY & DATA

If either Party will be using any third-party or pre-existing intellectual property (including, but not limited to copyrighted works, known patents, trademarks, service marks and trade secrets) "IP" and/or Data with restrictions on use, then list all such IP/Data and the nature of the restriction below. If no third-party or pre-existing IP/Data will be used, check "none" in this section.

A. State: Preexisting Intellectual Property (IP)/Data to be provided to the University from the State or a third party for use in the performance in the Scope of Work.

☒ None or ☐ List:

Owner (State Agency or 3rd Party)	Description	Nature of restriction:

B. University: Restrictions in Preexisting IP/Data included in Deliverables identified in Exhibit A1, Deliverables.

☒ None or ☐ List:

Owner (University or 3rd Party)	Description	Nature of restriction:

C. Anticipated restrictions on use of Project Data.
If the University PI anticipates that any of the Project Data generated during the performance of the Scope of Work will have a restriction on use (such as subject identifying information in a data set), then list all such anticipated restrictions below. If there are no restrictions anticipated in the Project Data, then check "none" in this section.

☒ None or ☐ List:

Owner (State Agency or 3rd Party)	Description	Nature of restriction:

EXHIBIT A5

RÉSUMÉ / BIOSKETCH

Attach 2-3 page Résumé/Biosketch for Key Personnel listed in Exhibit A2.

Please find them in the combined PDF here.

EXHIBIT A6

CURRENT & PENDING SUPPORT

University will provide current & pending support information for Key Personnel identified in Exhibit A2 at time of proposal and upon request from State agency. The "Proposed Project" is this application that is submitted to the State. Add pages as needed.

PI: Jiayu Li					
Status	**Award #**	**Source**	**Project Title**	**Start Date**	**End Date**
Proposed project		CARB	Laboratory and Community Evaluation of Advanced Portable Air Cleaners and HVAC Filters for Indoor Gas Pollutants	1/1/2026	12/31/2027
Proposed project		AHSRAE	Effect of residential exhaust terminations on jet mechanics and resulting required intake separation	9/1/2025	8/31/2027
Proposed project		AHSRAE	The Verification of openings, the limitations of openings, air distribution and humidity conditions in Naturally Ventilated spaces	9/1/2025	12/31/2027
Active	24STC015	CARB	Quantification Methodology for Estimating the Benefits of Air Filtration	5/29/2025	8/29/2026
Active	IUT: 7721216	Intra-University Transaction Agreement	Research and Development to Support In-Situ Evaluations of Air Mixing Impacts on Germicidal Ultraviolet Disinfection and Far-UVC By-products in Buildings	3/3/2025	12/31/2025
Active	IUT: 7733231	Intra-University Transaction Agreement	Commercial Kitchen Indoor Environmental Quality (IEQ) Field Study	1/1/2024	12/31/2025

Co-PI: Stefano Schiavon					
Status	**Award #**	**Source**	**Project Title**	**Start Date**	**End Date**

Proposed project		CARB	Laboratory and Community Evaluation of Advanced Portable Air Cleaners and HVAC Filters for Indoor Gas Pollutants	1/1/2026	12/31/2027
Proposed project		AHSRAE	The Verification of openings, the limitations of openings, air distribution and humidity conditions in Naturally Ventilated spaces	9/1/2025	12/31/2027
Proposed project		AHSRAE	Development of View Clarity Metrics for Fenestration Systems.	9/1/2025	07/31/2027
Active	IUT: 800727	Intra-University Transaction Agreement	Occupant IEQ Survey 2025 for Renew America's Schools	2/1/2025	01/31/2026
Active	IUT: 7721216	Intra-University Transaction Agreement	Research and Development to Support In-Situ Evaluations of Air Mixing Impacts on Germicidal Ultraviolet Disinfection and Far-UVC By-products in Buildings	3/3/2025	12/31/2025
Active	IUT: 7733231	Intra-University Transaction Agreement	Commercial Kitchen Indoor Environmental Quality (IEQ) Field Study	1/1/2024	12/31/2025
Active	#41949	CARB	Analyzing Cost-Effectiveness and Mitigation Potential of Low-Carbon Building Material Alternative	04/01/2025	03/31/2027
Active		Singapore NRF	Heat Exposure, AcTivity, and Sleep. Funder: Singapore National Research Foundation	01/01/2024	12/31/2026
Active		California Department of Housing and Community Development	Establishing Maximum Thermal Conditions for California Residential Dwellings (AB209	06/01/2023	12/31/2025

Co-PI: Haofei Zhang					
Status	**Award #**	**Source**	**Project Title**	**Start Date**	**End Date**
Proposed project		CARB	Laboratory and Community Evaluation of Advanced Portable Air Cleaners and HVAC Filters for Indoor Gas Pollutants	1/1/2026	12/31/2027

Proposed project		NSF	Multiphase Oxidation of Organic Aerosols under Various Environmental Conditions	7/1/2025	6/30/2028
Active	2037698	NSF	Collaborative Research: Reframing Modeling Approaches for Multiphase Chemistry--Isoprene and Beyond	5/15/2021	12/31/2025
Active	DE-SC0023330	DOE	Collaboration with the ARM and EMSL Facilities to Study the Composition and Hygroscopicity Relationship in Atmospheric Aerosols	5/1/2022	4/30/2026
Active	15206sc03	TRDRP (UCSF subcontract)	California Collaborative Consortium on Thirdhand Smoke Pilot Award: Aging of Tobacco-Specific Nitrosamines on Indoor Surfaces	3/1/2024	10/31/2025

Xiaochen Tang					
Status	**Award #**	**Source**	**Project Title**	**Start Date**	**End Date**
Proposed project		CARB	Laboratory and Community Evaluation of Advanced Portable Air Cleaners and HVAC Filters for Indoor Gas Pollutants	1/1/2026	12/31/2027
Active	T32PT5965	TRDRP	THS Chemistry: Exposure Assessment, Quantification Metrics and Remediation	12/1/2022	11/30/2026
Active	T32IR4867	TRDRP (UCSF subcontract)	Measuring Environmental Tobacco and Cannabis: Pollutants and Exposures	7/1/2022	6/30/2025
Active	IUT: 7721216	Intra-University Transaction Agreement	Research and Development to Support In-Situ Evaluations of Air Mixing Impacts on Germicidal Ultraviolet Disinfection and Far-UVC By-products in Buildings	3/3/2025	12/31/2025

Michelle Wong

Status	Award #	Source	Project Title	Start Date	End Date
Proposed project		CARB	Laboratory and Community Evaluation of Advanced Portable Air Cleaners and HVAC Filters for Indoor Gas Pollutants	1/1/2026	12/31/2027
Proposed project		Cal/EPA	Climate Health Adaptation and Resilience Mobilization (CHARM) Lake County	06/01/2025	05/31/2027
Proposed project		Cal/EPA	Mendocino Lake Sonoma Tribal Air Information and Resources (MLS Tribal AIR)	06/01/2025	05/31/2027
Proposed project		Rose Foundation	Youth for Clean Air Fruitvale	09/01/2025	08/31/2026
Proposed project		CDSS	Guaranteed Income Pilot Program for Older Adults	02/01/2026	08/31/2029
Active	OT2HL158287	NIH	Community Health Adaptation and Resilience Mobilization (CHARM) Lake County- Phase II	06/04/2025	06/03/2029
Active	026452-2025-02-24	Environmental Justice Data Fund	Lithium Valley Impacts Monitoring Tool	02/01/2025	01/31/2027
Active	SPPD23120	CA Governor's Office of Land Use and Climate Innovation	Mendocino, Lake, Sonoma Tribal Resilience Initiative on Air quality and Drought (MLS-TRIAD)	07/19/2024	02/28/2026
Active	80NSSC22K1684	NASA	Mapping Vulnerable Populations in California to Climate-Related Hazards	01/01/2023	12/31/2025
Active		Waverly Street Foundation	Lithium Valley	01/01/2025	12/31/2025

EXHIBIT A7

THIRD PARTY CONFIDENTIAL INFORMATION

CONFIDENTIAL NONDISCLOSURE AGREEMENT

Exhibit A7 is not applicable for this Agreement.

Exhibit B3 – Invoice Elements
Invoice and Detailed Transaction Ledger Elements

In accordance with Section 14 of Exhibit C – Payment and Invoicing, the invoice, summary report and/or transaction/payroll ledger shall be certified by the University's Financial Contact and the PI (or their respective designees).

Summary Invoice – includes either on the invoice or in a separate summary document – by approved budget category (Exhibit B) – expenditures for the invoice period, approved budget, cumulative expenditures and budget balance available[1]

- Personnel
- Equipment
- Travel
- Subawardee – Consultants
- Subawardee – Subcontract/Subrecipients
- Materials & Supplies
- Other Direct Costs
    - TOTAL DIRECT COSTS (if available from system)
- Indirect Costs
    - TOTAL

Detailed transaction ledger and/or payroll ledger for the invoice period [2]

- Univ Fund OR Agency Award # (to connect to invoice summary)
- Invoice/Report Period (matching invoice summary)
- GL Account/Object Code
- Doc Type (or subledger reference)
- Transaction Reference#
- Transaction Description, Vendor and/or Employee Name
- Transaction Posting Date
- Time Worked
- Transaction Amount

[1] If this information is not on the invoice or summary attachment, it may be included in a detailed transaction ledger.

[2] For salaries and wages, these elements are anticipated to be included in the detailed transaction ledger. If all elements are not contained in the transaction ledger, then a separate payroll ledger may be provided with the required elements.

EXHIBIT D

ADDITIONAL REQUIREMENTS ASSOCIATED WITH FUNDING SOURCES

If the Agreement is subject to any additional requirements imposed on the funding State agency by applicable law (including, but not limited to, bond, proposition and federal funding), then these additional requirements will be set forth in Exhibit D. If the University is a subrecipient, as defined in 2 CFR 200 (Uniform Guidance on Administrative Requirements, Audit Requirements and Cost Principles for Federal Financial Assistance), and the external funding entity is the federal government, the below table must be completed by the State agency. (Please see sections 10.A and 10.B of the Exhibit C.)

State Agency to Complete (Required for Federal Funding Source):

Federal Agency	
Federal Award Identification Number	
Federal Award Date	
Catalog of Federal Domestic Assistance (CFDA) Number and Name	
Amount Awarded to State Agency	
Effective Dates for State Agency	
Federal Award to State Agency is Research & Development (Yes/No)	

University to Complete:

Research and Development (R&D) means all research activities, both basic and applied, and all development activities that are performed by non-Federal entities. The term research also includes activities involving the training of individuals in research techniques where such activities utilize the same facilities as other R&D activities and where such activities are not included in the instruction function.

This award ☑ does ☐ does not support Research & Development.

EXHIBIT E

SPECIAL CONDITIONS FOR SECURITY OF CONFIDENTIAL INFORMATION

Exhibit E is not applicable for this Agreement.

EXHIBIT F

ACCESS TO STATE FACILITIES OR COMPUTING RESOURCES

Exhibit F is not applicable for this Agreement.

EXHIBIT G

NEGOTIATED ALTERNATE UTC TERMS

I. **Exhibit C, UTC – 220 Section 14 – Payment & Invoicing is hereby amended to incorporate the following:**

Add Item 6 to Section 14. A. to read as follows:

6) CARB shall withhold payment equal to 10 percent after the Contractor has been compensated for 90 percent of the total agreement amount. The 10 percent shall be withheld until completion of all work and submission to CARB by the University of a final report approved by CARB in accordance with Exhibit A1, Schedule of Deliverables, Section 2. It is the University's responsibility to submit one (1) original and one (1) copy of the final invoice.

Amend Section 14. C.2 – Invoicing to read as follows:

2) Invoices shall be submitted in arrears not more frequently ~~than monthly and not less frequently~~ than quarterly to the State Financial Contact, identified in Exhibit A3. Invoices may be submitted electronically by email. If submitted electronically, invoice must include the following certification for State certification to the State Controller's Office, in compliance with SAM 8422.1

This bill has been checked against our records and found to be the original one presented for payment and has not been paid. We have recorded this payment so as to prevent later duplicate payment.

Signed: _____
State Agency Accounting Officer

Add Item E: to Section 14, to read as follows:

E. Advance Payment

1) Nothing herein contained shall preclude advance payments pursuant to Title 2, Division 3, Part 1, Chapter 3, Article 1 of the Government Code of the State of California.

2) Upon termination or completion of this Agreement, Contractor shall refund any excess funds to the CARB. Contractor will reconcile total Agreement costs to total payments received in advance and any remaining advance will be refunded to the CARB's Accounting Office. In the event the Agreement is terminated, total project costs incurred prior to the effective date of termination (including close-out costs) will be reconciled to total project payments received in advance and any remaining advance will be refunded to the CARB. In either

event Contractor shall return any balance due to CARB within sixty (60) days, of expiration or earlier termination.

Amend Section 14.B –Budget Flexibility to read as follows:

B. Budget revisions between identified budget categories in cost reimbursement agreements that are within the total Agreement amount, comply with the Prior Approval Requirements, above and do not change the Scope of Work or substitute Key Personnel, as defined in this Agreement, are allowed as described below:

1) Up to 10% ~~of each annual budget amount or $10,000, whichever is less,~~ is allowed with approval of the State's Contract Project Manager, or as otherwise agreed to by the Parties and documented on Exhibit B.

2) Exceeding 10% ~~or $10,000, whichever is less,~~ of the last approved budget require the State's Contract Project Manager's prior approval and may require a formal amendment to this Agreement. The University will submit a revised budget to the State for approval. Budget transfers that would cause any portion of the funds to be used for purposes other than those consistent with the original intent of this Agreement are not allowed.

II. Add the following sections to the UTC-220 to incorporate additional required provisions:

Add Section 31 to read as follows:

31. GenAI Disclosure Obligations:

A. The following terms are in addition to the defined terms and shall apply to the Contract:

1) "Generative AI (GenAI)" means an artificial intelligence system that can generate derived synthetic content, including text, images, video, and audio that emulates the structure and characteristics of the system's training data. (Gov. Code § 11549.64.)

B. Contractor shall immediately notify the State in writing if it: (1) intends to provide GenAI as a deliverable to the State; or (2), intends to utilize GenAI, including GenAI from third parties, to complete all or a portion of any deliverable that materially impacts: (i) functionality of a State system, (ii) risk to the State, or (iii) Contract performance. For avoidance of doubt, the term "materially impacts" shall have the meaning set forth in State Administrative Manual (SAM) § 4986.2 Definitions for GenAI.

C. Notification shall be provided to the State designee identified in this Contract.

D. At the direction of the State, Contractor shall discontinue the provision to the State of any previously unreported GenAI that results in a material impact to the functionality of the System, risk to the State, or Contract performance, as determined by the State.

E. If the use of previously undisclosed GenAI is approved by the State, then Contractor will update the Deliverable description, and the Parties will amend the Contract accordingly, which may include incorporating the GenAI Special Provisions into the Contract, at no additional cost to the State.

F. The State, at its sole discretion, may consider Contractor's failure to disclose or discontinue the provision or use of GenAI as described above, to constitute a material

breach of Contract when such failure results in a material impact to the functionality of the System, risk to the State, or Contract performance. The State is entitled to seek any and all remedies available to it under law as a result of such breach, including but not limited to termination of the contract.

Add Section 32 to read as follows:

32. Health and Safety

Contractors are required to, at their own expense, comply with all applicable health and safety laws and regulations. Upon notice, Contractors are also required to comply with the state agency's specific health and safety requirements and policies.
Contractors agree to include in any subcontract related to performance of this Agreement, a requirement that the subcontractor comply with all applicable health and safety laws and regulations, and upon notice, the state agency's specific health and safety requirements and policies.

Add Section 33 to read as follows:

33. Executive Order N-6-22 – Russia Sanctions

On March 4, 2022, Governor Gavin Newsom issued Executive Order N-6-22 (the EO) regarding Economic Sanctions against Russia and Russian entities and individuals. "Economic Sanctions" refers to sanctions imposed by the U.S. government in response to Russia's actions in Ukraine, as well as any sanctions imposed under state law. The EO directs state agencies to terminate contracts with, and to refrain from entering any new contracts with, individuals or entities that are determined to be a target of Economic Sanctions. Accordingly, should the State determine Contractor is a target of Economic Sanctions or is conducting prohibited transactions with sanctioned individuals or entities, that shall be grounds for termination of this agreement. The State shall provide Contractor advance written notice of such termination, allowing Contractor at least 30 calendar days to provide a written response. Termination shall be at the sole discretion of the State.