Appendix F – Database of Research Priorities Submitted to CARB for Consideration in the Five-Year Strategic Research Plan

Community-Based Organization Engagement Process

In Fall 2023, CARB *put out a call* to recruit interested Tribes and community-based organizations (CBOs) to work with CARB in developing environmental justice research priorities for the Five-Year Strategic Research Plan. Seven CBOs were invited to contract with CARB for one year, attend three meetings between CARB and the CBO partners, and co-host seven research roundtables, six of which were held in person within their respective communities.

The seven partners recruited for this effort include *United for Justice*, *Orange County Environmental Justice*, *Breathe Southern California*, *Central California Asthma Collaborative*, *Climate Resilient Communities*, *Benicia Community Air Monitoring Program*, and *Alianza Coachella Valley*.

The goals for each meeting are provided in the following section. Summaries of the six in-person and one virtual research roundtables are publicly available and linked below.

Community-Based Organization Meeting Plan

Before and after each meeting, CARB provided CBOs with materials for review and feedback. To ensure alignment and advance actionable outcomes, CARB also held internal planning sessions and coordinated with relevant external agencies as needed.

Table 1: Chronological order of all CBO meetings with descriptions.

Meeting Date	**Description**
Meeting 1: Apr 29, 2024	• Introductions, outline the process, discuss meeting agreements, and process expectations. • Use the consensus workshop model to generate and group research ideas. • Roundtable Meeting Plan and ideas for outreach.
Meeting 2: Jun 4, 2024	• Present environmental justice research questions from meeting 1. • Correct mistakes, refine, and prioritize questions. • Discuss who would benefit from this work. • Understand statewide implications. • Agree on the Roundtable Meeting approach and finalize the outreach plan.

Meeting 3: Aug 26 - Sep 23, 2024	See Table 2
Meeting 4: Dec 2, 2024	• Discussed potential public outreach strategies and engagement plans on these topics. • Discussed next steps, how this effort will be reflected in the Five-Year Plan, and what people can expect moving forward.

Table 2: Summary of research roundtable date, location, and CBO co-hosts. The meeting summaries for each meeting are linked in the location.

Date	**Location**	**CBO Co-Host**
Aug 26	*Niland* Bombay Beach Community	United for Justice
Aug 27	*Santa Ana* Delhi Center	Orange County Environmental Justice
Aug 29	*Online*	
Sep 11	*Los Angeles* Pico Union Project	Breathe Southern CA
Sep 12	*Lamont* Bear Mt Rec Center	Central California Asthma Collaborative
Sep 18	*East Palo Alto* YMCA	Climate Resilient Communities
Sep 23	*Richmond* Memorial Auditorium	Benicia Community Air Monitoring Project

The meeting summaries linked in the table provide detailed notes of how each meeting was facilitated. An overall summary is available on the CARB *website*.

The goal of each meeting was to develop new environmental justice research questions and refine existing questions based on meeting participant feedback and academic input from roundtable meetings. An additional goal was to provide a networking opportunity for researchers and CBOs to build or extend relationships.

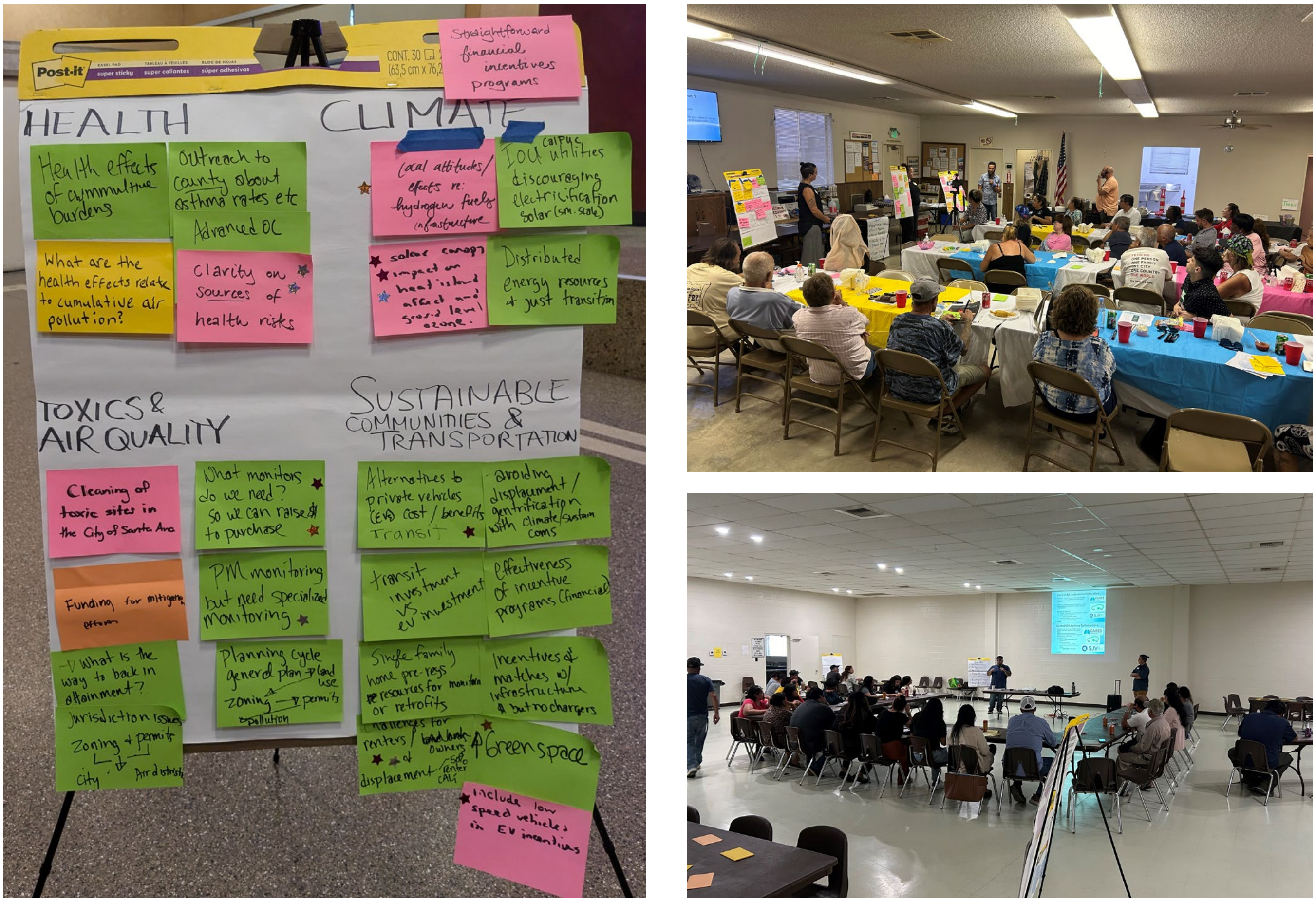

Figure 1: The left picture shows the sticky notes collected from community members attending the Santa Ana meeting. The upper right picture shows the Bombay meeting. The lower right picture shows the Lamont meeting.

After summarizing the input from the roundtables, CBOs and CARB staff reviewed the research questions to ensure they were distinct and complementary. CARB and CBOs then worked to finalize and prioritize the research questions.

Final List of Future Priorities

The following section summarizes the future research priorities that resulted from this process. The final step in this collaborative effort was to ask the CBO partners to rank the future research priorities by urgency. The ranking is noted in the title of the research priority. All input is minimally formatted to retain the original intent of the person who submitted it. Therefore, the language, statements, recommendations, and conclusions provided in the following tables are not necessarily those of CARB. The mention of commercial products, their sources, or their use in connection with material reported herein should not be construed as an actual or implied endorsement by CARB.

Health Research

Public Health Risks from Climate Change and Multi-Pollutant Exposure (Ranked 1st)

- What are the greatest public health risks from climate change and multi-pollutant exposure? Where and who is most at risk? How are disparity gaps closed?
- How are the immediate and long-term health impacts of chronic and acute exposure to air pollution and climate-related stressors in priority communities? What risk disparities exist, and what strategies can close the gaps?
- Health impacts include asthma, COPD, lung cancer, heart disease, strokes, and mental health. Other health indicators include emergency room visits, hospitalizations, missed school and work, and inhaler prescriptions.
- Cumulative pollution sources vary by location but could include traffic, refineries, airports, chemical plants, ports and docks, landfills, metal operations, local industries, and agriculture. Acute exposure includes flaring or toxic releases.
- Pollutants include particulate matter 2.5, ozone, ammonia, methane, volatile organic compounds, nitrogen oxides, and hydrogen sulfide.
- Climate-related stressors include heat, wildfires, soil aridification, and flooding with subsequent airborne silt.
- Unique location circumstances and impacts. For example, the Salton Sea has the Sea, lithium development, agriculture, and dust. The Central Valley has agriculture and oil and gas development.
- Sub-populations of interest include children, pregnant people, elders, farm workers, and unhoused residents. For example, what are the long-term health impacts of wildfire smoke and extreme heat on subpopulations, including nursing home residents, wildfire fighters, incarcerated people, farmworkers, and unhoused community members?
- Cumulative pollution sources vary by location but could include traffic, refineries, airports, chemical plants, ports and docks, landfills, metal operations, local industries, and agriculture. Acute exposure includes flaring or toxic releases.

Pollutants include particulate matter 2.5, ozone, ammonia, methane, volatile organic compounds, nitrogen oxides, and hydrogen sulfide.

Adaptation Approaches (Ranked 2nd)

- What are the most effective adaptation approaches to addressing climate impacts in vulnerable communities?
- What are the costs and co-benefits of different heat adaptation approaches? Costs and benefits related to economic, ecological, air quality, climate, physical health, and mental health. Strategies include infrastructure improvements such as cool roofs, road painting, nature-based solutions, green spaces, and tree canopies. What are the impacts of extreme heat on energy costs, energy reliability, health impacts of energy blackouts, and the lack of emergency shelters?

Long-Term Health Effects of Wildfire Smoke (Ranked 3rd)

- Long-term health effects of wildfire smoke in isolation and in addition to existing poor air quality. What are the long-term health impacts of wildfire smoke in fire hazard severity zones and downwind when added to existing poor indoor and outdoor air quality?

Air Quality and Public Health Impacts of Agricultural Practices in a Changing Climate (Ranked 4th)

- What are the air quality and public health impacts of agricultural practices in a changing climate?
- What are the air pollution and health impacts of fertilizer and pesticide application, especially from planes, dusters, blasters, and drifts? How far do pesticides and herbicides drift? Farmworkers and children emerged as populations of concern.
- What are the cumulative long-term respiratory health effects of dust/sandstorms, pesticides and fertilizers, poor air quality, and other events?
- What are the impacts of climate change on pests and subsequent potential increases in pesticide applications?
- How will climate-amplified droughts impact farmland and the pesticides that drift, especially during dry periods and dusting?

Toxic Chemicals in Entrained Dust from the Salton Sea (Ranked 5th)

- What inflammatory and/or toxic chemicals are adsorbed or entrained in the dust from the exposed Salton Sea lakebed? Monitoring for Salton Sea community exposure to airborne pollutants from the exposed playa. Air quality and health research on the interactions between Salton Sea water and dust, and the possibility that a new respiratory disease has emerged and is misdiagnosed as asthma.

Impact of Scale on Understanding Air Quality, Climate, and Health Disparities (Ranked 6th)

- What difference does scale make in understanding air quality, climate, and health disparities in priority communities?

Air Quality Research

Impact of Climate Change on Air Quality Disparities (Ranked 1st)

- What are the impacts of climate change on air quality disparities, especially the relationships between heat, particulate matter 2.5, and ozone?

Equitable Monitoring (Ranked 2nd)

- What is the best approach for equitably monitoring local disparities and their reductions?
- How can regulatory monitors be more equitably placed to measure localized disparities with opportunities for enforcement?
- What are the best ways to develop, fund, and implement enforceable community monitoring?
- Notes: Extensive requests arose for increased monitoring, transparent monitoring siting decisions, source attribution research, accessible and understandable data, and enforceable fenceline monitoring in priority communities. Regulatory monitors are often 5-10 miles away and will not pick up local disparities. Purple air monitors are not enforceable and depend on unreliable WI-FI. Communities suggested that CARB convene a community air monitoring community of practice to facilitate sharing data and best practices.

Impact of Industrial Operations on Air Quality Disparities (Ranked 3rd)

- What are the emissions and air quality impacts from industrial operations such as metal operations, ports, granite cutting, or local operations like crematoriums? Emissions of interest include particulate matter, volatile organic compounds, nitrogen oxides, sulfur dioxide, dioxins (PCDD/Fs), mercury, and ozone.

Drivers of Future PM2.5 Formation (Ranked 4th)

- What are the drivers of future particulate matter 2.5 formation?

Impact of Climate Change on Air Quality Disparities (Ranked 5th)

- What are the impacts of climate change on air quality disparities, especially the relationships between heat, particulate matter 2.5, and ozone? What are the best approaches to ensuring sustained improvements?

Impact of Agricultural Activities on Air Quality Disparities (Ranked 6th)

- What are the air quality impacts of agricultural burning, tilling, and harvesting? For example, what are the seasonal PM 2.5 and PM10 impacts from almond harvesting?

Climate Research

Clean Energy Transition Impact on Air Quality (Ranked 1st)

- How will industrial operations and air quality change in the clean energy transition? Industrial operations include refineries, airports, local industries, landfills, ports, and agriculture. How will refinery emissions change with the transition to biofuels and hydrogen production? How will hydrogen fuel production impact nitrogen oxides and ozone emissions?

Co-Benefits of Air and Climate Strategies (Ranked 2nd)

- What are the co-benefits of air quality and climate strategies?
- How are the economic, air quality, health, and climate co-benefits of the Scoping Plan and other strategies distributed, especially in environmental justice communities? Other strategies include Cap-and-Trade, the Low-Carbon Fuel Standard, biofuels, electric vehicle incentives, and enforcement fines.
- How is air quality and climate money spent, and is it effective?
- How effective are attainment strategies, and how can new plans be improved?

Long-Term Health Effects of Wildfire Smoke (Ranked 3rd)

- How will wildfire emissions change in response to climate change? What are the air quality impacts from wildfire burn scars?

Affordable Housing and Wildland Urban Interface (Ranked 4th)

- How does the lack of affordable housing impact air quality via increasing vehicle miles traveled, people moving into the wildland-urban interface, and increasing structures that may burn?

Mobile Sources Research

High Emitters (Ranked 1st)

- What are effective ways to measure and identify high emitters in priority communities? Including issues like idling.

Warehouse Growth and Impact on Nearby Neighborhoods (Ranked 2nd)

- How does warehouse growth impact heavy-duty traffic and mobile pollution sources? What strategies can reduce PM and diesel pollution in priority communities without displacing it to other communities?
- How does increasing freeway and side street traffic and congestion impact indoor air quality? What are the most effective mitigation strategies?

Brake and Tire Wear (Ranked 3rd)

- What is the variance among brake and tire wear by vehicle types (i.e., electric vehicles vs. internal combustion engines vs. off-road/construction)? Is there greater brake and tire wear from heavier batteries in electric vehicles or street conditions?

Sustainable Transportation, Housing, and Communities Research

Benefits of Public Transit and Walkable, Bikeable, and Accessible Cities (Ranked 1st)

- What are the economic, physical, and mental health benefits of public transit and walkable, bikeable, and accessible cities?

Additional Priorities Collected Through the CBO Process

The following table contains a summary of input received on general research planning methods and communication strategies. All input is minimally formatted to retain the original intent of the person who submitted it. Therefore, the language, statements, recommendations, and conclusions provided in the following tables are not necessarily those of CARB. The mention of commercial products, their sources, or their use in connection with material reported herein should not be construed as an actual or implied endorsement by CARB.

Table 3: Summary of recommendations collected through the CBO process on communication and research methods.

Category	**Description**
Raising Awareness	How does the community best understand climate change and air quality impacts, and how can agencies change their communication to suit those needs? What messaging, outlets, and approaches work best?
Health Protective Measures	What education and outreach approaches are most effective for priority communities to understand and address indoor air quality? Are there more effective ways to communicate outdoor and indoor air quality concerns with schools to protect student health?
Tools and Data	The public is interested in seeing more tools and maps that overlay cumulative risks, including climate, air quality, health, and emergency-related data layers. What tools are needed to make this information accessible to the public? What current data can be leveraged and combined to create this cumulative risk assessment? Can newer tools like smart thermostats trigger air filters or cleaners to address indoor air quality? What other types of sensors and tools can be used, and are they effective at triggering health protective measures?
Incentives	What are the best communication methods to raise awareness of incentive programs? What is the best way to inform people about rebates and other benefits of buying zero-emission vehicles, heating and cooling pumps, stoves, and other decarbonization incentives? Are guides for low-income communities or landlords effective? What incentives and policies are most effective in transitioning to walkable, bikeable, or transit-accessible cities?
Emergency Preparedness	What outreach and communication approaches increase awareness of climate change and air quality and improve public responses to hazards (i.e., heat waves, air quality, wildfire) and associated health impacts?

Methodologies	Increase in community science and community-engaged research. Especially important in validating community concerns.
Research Planning	Research should be planned with implementation in mind and centered on actionable outcomes that can address disparities or provide material benefits to communities.
Community Engagement and Participation	Communities deserve a seat at the table. How do we streamline the process for communities to receive the support and resources from organizations like CARB to begin mitigating these problems? Need easy-to-understand and accurate dashboards to help improve awareness and transparency. Low-cost sensors are a low priority. Many sensor projects have been undertaken through the AB617 program and others. People are more interested in nature-based solutions and multi-function solutions.

Public Engagement Process

In addition to the CBO process described above, a public engagement process was developed to collect input on future research priorities that would be considered for inclusion in the Five-Year Plan. CARB staff reviewed all the input and applied the similar criteria used when selecting annual research projects. Those criteria are available on the research comment portal.

Timeline of Engagement

The public engagement process is outlined in chronological order below, and relevant links to surveys or materials are provided for each item.

Table 4: Chronological order of all public engagement steps with date, links to publicly available documents, and descriptions.

Date/Item	Links	Description
Feb 29, 2024 – Public meeting	Public meeting *slides*. Public meeting *recording*.	A polling tool was used to record breakout session responses. Sample from Air Quality/Climate breakout room: • Submit one word or phrase that comes up when you think of air quality or climate research? • What are some major concerns impacting you personally or that you've heard the public express in the air quality and climate research area? • What is at the core of these concerns? • What are the research questions that should be asked in the next 5 years to address the most pressing concerns in air quality and climate within CARB's purview?
Apr 10, 2024 – Survey Closed	*Link to survey* (now closed).	Each year, CARB collects comments and concepts from the public using a survey with separate options for comments and concepts. For fiscal year 2025-2026, a third option was added to collect research priorities that CARB could consider for the proposed Five-Year Plan. This third option provided a long-form response space where the survey respondent could describe a proposed research priority.

Nov 18 and 20, 2024 – Public Meeting	Public meeting *slides*. Public meeting *recording*.	CARB hosted a public meeting to discuss its fiscal year 2025-2026 research priorities and the proposed research initiatives for the Five-Year Plan. The meeting's purpose was to solicit comments from the public on both of these items. A brief presentation was given, and then breakout room discussions were held on the major research categories.
Nov 30, 2024 – Academic Surveys Closed	Example of the *Air Quality Research Priorities survey* (now closed).	CARB created a survey targeted at academic contacts who had contracted or collaborated with CARB previously, or who have expertise in their field of research. Separate but similar surveys were created for Health, Air Quality, Climate, Mobile Sources, and Sustainable Communities.

All Input By Topic

The following tables contain anonymized input collected with the comment and concept survey, from various meetings CARB staff attended, and from the academic surveys administered later in 2024. These tables are being provided for transparency. All input is minimally formatted to retain the original intent of the person who submitted it. Therefore, the language, statements, recommendations, and conclusions provided in the following tables are not necessarily those of CARB. The mention of commercial products, their sources, or their use in connection with material reported herein should not be construed as an actual or implied endorsement by CARB. Input has been categorized to align with the research initiative topics in the Five-Year Strategic Research Plan.

Health – Health and Climate

Source	**Comment/Priority**
Public comment/concept survey	Health impacts and life cycle assessments of CCS, CCUS, and DAC technologies.
Public meeting - Breakout room survey	The Tribal Climate Health Project has two significant research projects that may be of interest to CARB and would welcome collaboration with CARB. 1) BIA award to complete an analysis and white paper on the current status of wildfire-related illness (and groundwater) data access for Tribes. 2) CEC/OPR Tribal Research Program Grant award for adding functionality to PHI's CA Healthy Places Index for tribal climate and health vulnerability indicators.

Public meeting	People in my neighborhood use their fireplaces throughout the winter, even on no-burn days, because they're unaware there are no-burn days. People don't understand the health impacts of exposure to smoke, and that smoke is trapped in the valley during the winter months. How do we communicate how activities in their home can impact air quality in their neighborhood and even regionally?
LERN Workshop	Visits diagnosed as heat/cold event-related, but need to research more about the impacts on comorbidities.
LERN Workshop	Unpredictable weather: from record drought to record snowfall. Impacting our ability to plan, forecast, and address the health impacts.
LERN Workshop	New viruses and pests related to climate change and health impacts. The Sierras are being impacted by viruses and insects that have historically not been in this area. This is impacting our hospitals and staff significantly.
LERN Workshop	What are the long-term health impacts of exposure to wildfire smoke? Indoor air quality during wildfire smoke - messaging, filtration tools/appliances, equity of financing, and access to those tools.
AQ Academic Survey	Better understanding of sources of methane emissions is needed to identify potential ways to reduce emissions. Identification of potential sensitive subpopulations that may need additional risk messaging, e.g., pregnant people, specific life stages, that are not targeted with the current messaging. As society continues to transition to a net-zero future, and as communities invest in adaptation and resilience, CARB may also need to evaluate the protectiveness of air quality policies under different scenarios, accounting for both co-benefits and unintended negative consequences, e.g., emissions from mining of critical minerals.
Health Academic Survey	Effectiveness and equity of existing adaptation strategies, including air quality warning systems. Joint warning systems to incorporate co-occurring events such as extreme heat and wildfire smoke events. How to consider the specific composition and toxicity of PM2.5 from wildfire smoke and update existing policy responses? Advancing precision climate and health research by identifying interventions that would optimize health impacts in each community

Health Academic Survey	Aerosols from the environment can, under certain conditions, pose a significant health hazard. In particular, the microbiome in some ecosystems can produce significant amounts of bacterial toxins, which can then be aerosolized and inhaled by nearby residents. For example, at lakes that are drying due to the effects of climate change, exposed playa can produce dust laden with microbial toxins. Bacterial toxins, especially endotoxin/LPS, which are a natural product of Gram-negative bacteria, induce disproportionately strong lung inflammatory responses when inhaled. It is not considered a toxic chemical, as with pesticides, and it is not necessarily anthropogenic unless it comes from untreated sewage or livestock farming, yet in all cases, it poses a significant health hazard. Unfortunately, LPS levels are not assayed as an index pollutant, so this health hazard is absent from routine air quality monitoring. Detailed epidemiology studies need to be performed to assess the actual health impacts of aerosolized endotoxin/LPS in settings where exposure to this toxin in dust is likely. Moreover, new reliable assays need to be developed to measure endotoxin/LPS that include not only human clinical Gram-negative sources, but also environmental bacteria as well, since both sources produce strong host inflammatory responses. Considering the variety of man-made and environmental settings where endotoxin/LPS aerosols can be produced, research on these sources and health impacts will have a major impact on policy.
Health Academic Survey	One key knowledge gap is the ability to disentangle the influence of climate change from other factors that can determine health outcomes. Many environmental exposures are sensitive to climate, but we know less about how much anthropogenic climate change contributed to the burden. We will have new datasets from the upcoming CA Climate Assessment that will be critical to advancing climate-health research. This will be critical to both understand the influence of potential climate futures and the benefits of various adaptation measures.

Health – Indoor Air Quality

Source	**Comment/Priority**
Public comment/concept survey	Indoor air quality research for disadvantaged and low-income families in Southern California. This research will include data collection and on-site visits to many buildings and structures where these low-income families are occupying spaces with poor and infected air quality, with exposure to vapor and inert radioactive gases in the environment.
LERN Workshop	Indoor Air Quality standards for occupant health. (combustion byproducts)

AQ Academic Survey	Understanding actual exposures in a variety of settings is important. This includes not only outdoors but indoors, including inside and outside (i.e., non-exhaust emissions) vehicles. It also includes high-resolution measurements in disadvantaged communities to identify local sources that may be small enough to "fly under the radar" but have significant impacts. To do this, the development of small, portable, and RELIABLE sensors for a variety of air pollutants and climate gases needs to be developed, analogous to the Purple Air monitors for PM. Measuring individual metals and VOC would be great, in addition to the usual criteria pollutants. And data from them needs to be widely available, as with Purple Air.
Health Academic Survey	The scientific justification needed for IAQ standards is difficult to meet because there's just so much related to IAQ for which we lack good data/studies. One approach could be using a few well-known items, like CO_2, as proxies. Some sort of study looking at such proxies as indicators of IAQ and health could be very useful. It would also be useful to look into the ways extreme heat events can impact IAQ in different housing types (those meeting CA's new building standards vs those that don't, those with mechanical cooling systems and those that don't, etc.). Additional research is needed on the risks and benefits/efficacy of air cleaning technologies.
Health Academic Survey	Indoor-outdoor PM relationships in schools and homes, including institutional residences, and the barriers to using buildings and controls (air cleaners, central filtration, etc.) to reduce exposure to outdoor pollutants.
Health Academic Survey	Limited measured data on IAQ, exposures, and sources in dense-occupancy homes. Need better data on ventilation, sources & exposures in schools in disadvantaged communities, elder care facilities, prisons, and other high-risk spaces.

Health – Health Analysis

Source	**Comment/Priority**
Public meeting - Breakout room survey	Can we better quantify the health impact of toxic air contaminants on human health, including lost work hours, injuries, hospitalizations, and mortality? What are the costs of dealing with these impacts versus the costs of preventing them?

Public meeting	San Bernardino County faces significant air quality concerns, including a “Grade F” for air quality according to the American Lung Association's State of the Air. Air pollution is linked to preterm births, low birth weight, and stillbirth. SB’s valley location also makes it susceptible to thermal inversion, where air pollution is often trapped within the valley. Poor birth outcomes and high infant mortality rates. What are the specific pollutants and sources contributing to poor air quality in San Bernardino County, and how can regulatory measures effectively mitigate their impact on perinatal outcomes?
Health Academic Survey	We need long-term health studies. Currently, there are only a few cohort-based health studies in EJ areas around the US. We need more funds to follow populations who experience EJ issues.
Health Academic Survey	Lack of high-resolution, long-term exposure data on emerging pollutants (e.g., brake/tire wear, ultrafines), under-researched health impacts (e.g., mental health from cumulative exposures), and disparities in vulnerable communities.
Health Academic Survey	Primary knowledge gaps over the next five years include the health impacts of non-exhaust emissions, particularly from electric vehicles (EVs). As EV adoption accelerates, brake and tire wear and road dust resuspension will become increasingly significant sources of particulate matter (PM2.5) and toxic metals like copper, zinc, and lead. Data on these pollutants, their chemical composition, and exposure pathways are currently limited. Additionally, understanding the role of EV charging infrastructure, such as Direct Current Fast Chargers (DCFC), in contributing to localized PM2.5 concentrations is critical. More comprehensive monitoring and toxicological studies are needed to assess the cumulative health effects of these emerging sources on vulnerable populations.
Health Academic Survey	One idea is to explore new policy mechanisms (including regulations and legislation) to better address the cumulative impact from multiple sources of air pollution.
Health Academic Survey	Methods to more rapidly translate existing science into an actionable understanding of health effects from air emissions using existing science. Instead of new studies, CARB should invest in 1. systematic reviews of existing literature for uncertain or unknown health effects, 2. invest in methods to translate new methods for rapidly identify toxic chemical impacts (e.g. in vitro and in silico data) to hazard/risk information that can be used in decision making, and 3. to better account for susceptibilities due to intrinsic and extrinsic factors that will provide support to EJ communities/analyses.
Health Academic Survey	CARB has done a great job reducing PM2.5 exposures in many parts of the state. However, I think to make better decisions and health-based policies, we need to understand the role of constituents of PM2.5, not just PM2.5 as a single entity. This is especially true for wildfire and other non-vehicle emissions.

AQ Academic Survey	Develop air toxics, cancer, and non-cancer chronic health risk data for more pollutants. This should include both pollutants with established/known sources and exposures, but with unknown risk, and also new compounds being used in new/existing products, such as 6PPD and potential replacements for 6PPD in tires, and other products. Improve air toxics emissions data used for modeling air toxics with the highest potential health risks. Should focus on non-exhaust emissions, area sources, and improving the temporal and spatial allocation of emissions data in models to better represent real emissions.

Health – Air Toxics

Source	**Comment/Priority**
Public comment/concept survey	Addressing Airborne Microplastics and Associated Health Impacts 1. Introduction: The objective of this research plan is to investigate the presence, distribution, sources, and health impacts of airborne microplastics, including the harmful air pollutants they may carry. The research will focus on understanding the widespread distribution of microplastics, identifying sources, exploring measurement methods, and proposing strategies for mitigation. 2. Literature Review: Conduct a comprehensive review of existing literature on airborne microplastics, their sources, distribution, and potential health impacts. Identify gaps in knowledge and areas requiring further investigation. 3. Sampling and Analysis: Sample Collection: Collect air samples from various environments, including urban areas, industrial sites, coastal regions, and remote locations such as mountaintops. Particle Extraction: Use filtration and/or other extraction methods to isolate microplastic particles from air samples. Microscopic Analysis: Employ microscopy techniques (e.g., SEM, TEM) to characterize the size, shape, and composition of microplastic particles. Chemical Analysis: Conduct chemical analysis to identify and quantify harmful air pollutants attached to microplastics. 4. Health Impacts Assessment: Inhalation Exposure Assessment: Estimate the inhalation exposure of airborne microplastics and associated harmful air pollutants to humans. Toxicological Studies: Conduct toxicological studies to assess the potential health impacts of inhaling microplastics and attached pollutants on respiratory and systemic health. Risk Assessment: Quantify the potential risks posed by airborne microplastics to human health, considering exposure levels and toxicity of associated pollutants.

	5. Source Identification: Field Investigations: Conduct field studies to identify sources of airborne microplastics, including atmospheric deposition, vehicle emissions, industrial processes, and plastic waste. Modeling: Utilize atmospheric modeling techniques to simulate the transport and dispersion of microplastics and predict source contributions. 6. Measurement Methods: Particle Counting: Investigate the feasibility of using particle counters or optical instruments to measure airborne microplastic concentrations in real-time. Chemical Analysis: Develop analytical methods for quantifying microplastics and associated pollutants using spectroscopic or chromatographic techniques. Remote Sensing: Explore remote sensing technologies to detect and monitor microplastics in the atmosphere from satellite or aerial platforms. 7. Comprehensive Report and Recommendations: Compile research findings into a comprehensive report detailing the presence, distribution, sources, and health impacts of airborne microplastics. Provide recommendations for strategies to mitigate airborne microplastic pollution, including pollution prevention measures, waste management practices, and policy interventions. Emphasize the importance of interdisciplinary collaboration and public awareness in addressing the issue of airborne microplastics and protecting human health and the environment. 8. Conclusion: This research plan outlines a systematic approach to investigate airborne microplastics and associated health impacts, addressing their widespread distribution, sources, measurement methods, and mitigation strategies. By understanding the dynamics of airborne microplastics and their implications for human health, this research aims to inform evidence-based policies and interventions to minimize exposure and protect public health.
Public comment/concept survey	This research was done by Claudia Persico (http://www.nber.org/Papers/w30559), National Bureau of Economic Research, 1050 Massachusetts Avenue, Cambridge, MA 02138 Although Pollution Is Widespread, there is little evidence about how it might harm Children's long-term outcomes. Using the detailed, geocoded data that follows national representative cohorts of Children born to the national Longitudinal Survey of Youth respondents over, I compare Siblings who were gestation before versus after a Toxic Release Inventory site opened or closed within one mile of there home, I find that Children who were exposed prenatally to industrial pollution have lower wages, are more likely to be in poverty as adults, have fewer years of completed education, and are less likely to graduate high. (Centers for Disease Control and Prevention, 2009)

Public meeting - Breakout room survey	How to identify cancer hot spots and sources?
Public meeting - Breakout room survey	Can we better quantify the health impact of toxic air contaminants on human health, including lost work hours, injuries, hospitalizations, and mortality? What are the costs of dealing with these impacts versus the costs of preventing them?
Public meeting	People in my neighborhood use their fireplaces throughout the winter, even on no-burn days, because they're unaware there are no-burn days. People don't understand the health impacts of exposure to smoke, and that smoke is trapped in the valley during the winter months. How do we communicate how activities in their home can impact air quality in their neighborhood and even regionally?
LERN Workshop	Termite tents fumigation (use of pesticides) is an issue for human and animal health because the fumes are toxic, gas used are a major greenhouse gas contributor. Learning more about that and finding alternatives might be something we look at. Study on fumigating homes.
Health Academic Survey	What are the sources of air pollution that most impact disadvantaged communities? How do assessments of priority based on real-world measurements offer a different perspective compared to those arising from bottom-up emissions inventories? To what extent do undetected/unknown/under-reported sources of air pollution and air toxics contribute to disparate exposures in overburdened communities? How can these sources be better quantified? What types of policy actions offer the greatest potential to address air pollution disparities? How can these actions be better integrated into climate-change mitigation strategies?
Health Academic Survey	Primary knowledge gaps over the next five years include the health impacts of non-exhaust emissions, particularly from electric vehicles (EVs). As EV adoption accelerates, brake and tire wear and road dust resuspension will become increasingly significant sources of particulate matter (PM2.5) and toxic metals like copper, zinc, and lead. Data on these pollutants, their chemical composition, and exposure pathways are currently limited. Additionally, understanding the role of EV charging infrastructure, such as Direct Current Fast Chargers (DCFC), in contributing to localized PM2.5 concentrations is critical. More comprehensive monitoring and toxicological studies are needed to assess the cumulative health effects of these emerging sources on vulnerable populations.
Health Academic Survey	Methods to more rapidly translate existing science into an actionable understanding of health effects from air emissions using existing science. Instead of new studies, CARB should invest in 1. systematic reviews of existing literature for uncertain or unknown health effects, 2. invest in methods to translate new methods for rapidly identify toxic chemical impacts (e.g. in vitro and in silico data) to hazard/risk information that can be used in decision making, and 3. to better account for susceptibilities due to intrinsic and extrinsic factors that will provide support to EJ communities/analyses.

Health Academic Survey	CARB has done a great job reducing PM2.5 exposures in many parts of the state. However, I think to make better decisions and health-based policies, we need to understand the role of constituents of PM2.5, not just PM2.5 as a single entity. This is especially true for wildfire and other non-vehicle emissions.
AQ Academic Survey	Develop air toxics, cancer, and non-cancer chronic health risk data for more pollutants. This should include both pollutants with established/known sources and exposures, but with unknown risk, and also new compounds being used in new/existing products, such as 6PPD and potential replacements for 6PPD in tires, and other products. Improve air toxics emissions data used for modeling air toxics with the highest potential health risks. Should focus on non-exhaust emissions, area sources, and improving the temporal and spatial allocation of emissions data in models to better represent real emissions.

Health – Reducing Disparities

Source	**Comment/Priority**
Public meeting - Breakout room survey	How do socioeconomic factors exacerbate the impact of poor air quality on perinatal health outcomes within communities?
Public comment/concept survey	Research Priority: Development of Dust Storm Forecasting Capacity. Dust storms occur in many parts of the state, from Mono Lake south to the Owens Valley, the Mojave and Sonoran Deserts, and the San Joaquin Valley. Exposure to dust has been linked to a number of adverse health effects, ranging from asthma to Valley Fever to increased incidence of automobile accidents. Limiting exposure to dust should be a health priority. However, at present, there is no reliable forecast product for dust storms in the state. Thus, there is a need for a statewide effort to generate a reliable and actionable dust storm forecast product, including an early warning system to warn of an impending dust event.
Public meeting	San Bernardino County faces significant air quality concerns, including a "Grade F" for air quality according to the American Lung Association's State of the Air. Air pollution is linked to preterm births, low birth weight, and stillbirth. SB's valley location also makes it susceptible to thermal inversion, where air pollution is often trapped within the valley. Poor birth outcomes and high infant mortality rates. What are the specific pollutants and sources contributing to poor air quality in San Bernardino County, and how can regulatory measures effectively mitigate their impact on perinatal outcomes?

Health Academic Survey	What are the sources of air pollution that most impact disadvantaged communities? How do assessments of priority based on real-world measurements offer a different perspective compared to those arising from bottom-up emissions inventories? To what extent do undetected/unknown/under-reported sources of air pollution and air toxics contribute to disparate exposures in overburdened communities? How can these sources be better quantified? What types of policy actions offer the greatest potential to address air pollution disparities? How can these actions be better integrated into climate-change mitigation strategies?
Health Academic Survey	CARB is increasingly supporting high-resolution (or hyperlocal), community-scale air monitoring. However, we lack a systematic way of tracking real-world progress on addressing air pollution disparities in overburdened communities. Key gaps include: • How do we systematically monitor *trends* in air pollution at the fine-community scale over time? • To what extent is progress on air quality in individual communities being driven by local mitigation efforts (e.g., under AB617 or other targeted schemes), vs. a natural consequence of reduced emissions from major sources statewide? • How do we attribute changes in concentrations measured at monitors over time to changes in emissions? Community-scale inverse modeling efforts can play an important role in tracking progress over time & are an exciting area for methods development. • While CARB has tools (e.g., AQView) to serve as a central "warehouse" for community air monitoring data, new analytical methods to use these data are needed.
Health Academic Survey	Many of the air quality impacts are based on urban-level measurements. We need to understand more science of rural area air quality impacts from agriculture and natural phenomena like the Salton Sea, Owens Valley Lake, Tulare Lake, and others. The parameters and sampling methodology that are often applied to rural areas are taken from methods used in urban areas. We need more specific method development for rural areas.
Health Academic Survey	We need long-term health studies. Currently, there are only a few cohort-based health studies in EJ areas around the US. We need more funds to follow populations who experience EJ issues.
Health Academic Survey	Identifying and mitigating disproportionate pollutant exposures in marginalized communities. This includes assessing cumulative health impacts, understanding social determinants of vulnerability, and integrating community-driven data collection. Collaborating with county-level community health services departments that have a long-term relationship with community members to be more effective in engaging community outreach.

Health Academic Survey	To support environmental justice goals, research must focus on community engagement and granular-level health impact assessments. Studies should prioritize localized air quality monitoring in disadvantaged communities to better understand exposure to non-exhaust emissions, such as brake and tire wear and road dust, especially near high-traffic areas and EV charging stations. Additionally, cumulative health risk assessments are needed to capture the combined effects of multiple pollutants, including emerging sources from electric vehicle infrastructure. Collaborating directly with affected communities to gather real-time data, assess health disparities, and co-develop mitigation strategies will ensure that future policies address the unique needs and vulnerabilities of these populations.
Health Academic Survey	Literature scan/scoping review of current scientific understanding of differential response to air pollution due to social stressors and other factors relevant to highly impacted communities (EJ communities). Based on understanding from research, strategic investments are needed to improve the basis of the research that will provide data to improve decision-making. Improved air modeling and emissions data for better characterization of air pollution from point, mobile, and area sources at the community level
Health Academic Survey	We need more data on community interventions that are available to reduce environmental exposures, and how this varies across California's communities. Relatedly, this information could also help us to understand the effectiveness of policy-relevant tools and/or information campaigns, and how these efforts can be tailored for individual communities.

Air Quality – Future PM2.5

Source	**Comment/Priority**
Public meeting	Mobile measurements. Not enough data is collected. Toxics, VOC PM2.5 speciation for health concerns – UFP.
AQ Academic Survey	As we are transitioning from a typical "high-NOx" urban environment to a new "low-to-moderate NOx" regime, the chemical processes that control the production and spatial-temporal variations of PM2.5 in this new regime are far from being clearly understood.

AQ Academic Survey	No appreciable improvements have been seen in the design values of O_3 or PM2.5 since 2015 in any of the most polluted air basins in California. This observed fact contradicts all prior SIP modeling. Mounting evidence suggests that there are likely overlooked agricultural soil NOx emissions (as both NO and HONO) that are impacting air quality in many rural parts of the state. Wildfires are known to impact air pollution 1 in 5 days in the Central Valley during the warm season, and this effect is growing at an alarming rate, with a doubling time of 10-20 years. These sources are rapidly becoming the dominant air pollution concerns in the 21st century, and too much is uncertain about their overall emission amounts and timing. Both are very difficult to numerically model, and thus, emphasis should be placed on observational studies. Finally, the hemispheric background ozone concentrations dominate the ODV, and this source, primarily from stratosphere-troposphere exchange, needs to be studied.
AQ Academic Survey	How are the modeling tools we have limited in their predictive capability, and what does that mean for our limited ability to assess policy? For example, if we get O_3 right, but HOx and NOx wrong, is our model good?
AQ Academic Survey	Expectation of future AQ and climate implications (including PM, ozone, and CH_4) as wildfires increase and intensify; improved smoke transport models to facilitate increased use of prescribed fire to mitigate the size and severity of wildfires.
AQ Academic Survey	Pollution control policies have led to significant reductions of PM2.5 through the mitigation of precursors such as nitrogen oxides (NOx) and anthropogenic volatile organic compounds (VOCs); however, both natural and anthropogenic emissions of ammonia (NH_3) continue to contribute to PM2.5 globally. Sources of NH_3 in the troposphere include biomass burning and emissions from livestock waste, large-scale application of fertilizer, automobile emissions, and, to a lesser extent, industrial processes. Agricultural sources (e.g., crop fertilizer and livestock manure) contribute to over 57% of global NH_3 emissions, dominate NH_3 emissions in California, and are an important topic to be considered by the California Air Resources Board (CARB).
AQ Academic Survey	Significant knowledge gaps exist in understanding the chemical and physical properties of ambient PM at high spatial and temporal resolutions, affecting several areas: 1) rapidly identifying episodic events (e.g., wildfires) and assessing their health and environmental impacts; 2) analyzing spatial and temporal trends of PM components in communities impacted by localized sources; 3) linking PM components to human health to inform control policies; 4) identifying and quantifying PM sources to support strategies for meeting stringent PM2.5 standards; 5) improving forecasting, which is hindered by the lack of high-resolution, low-latency PM speciation data. More research and data are needed to enhance the monitoring of PM's physicochemical properties with high time resolution and lower costs for broader spatial coverage. Research on integrating surface measurements with satellite data to improve the understanding of PM chemical components at spatially comprehensive scales is strongly recommended.

AQ Academic Survey	Contributions of background PM2.5 to the area's design values. Contributions of non-exhaust emissions (i.e., tire and brake wear) to ambient PM2.5 levels.
AQ Academic Survey	Process understanding for PM2.5 formation, particularly for the SJV in the winter season. These processes include oxidation and multiphase chemistry, and understanding boundary layer dynamics and its interaction with emissions and chemistry. Wildfire emissions, chemistry, and transport for PM2.5 and O3 impacts require further research. The response of urban ozone and PM2.5 to continued reductions in NOx and VOC emissions, as well as sources of VOCs and potential for continued reductions, needs further study. Continued top-down analysis of emissions through satellite, aircraft, or ground-based observations to validate and refine inventories. Of particular interest will be sources of NOx from urban sources and soils.
AQ Academic Survey	In general, we need to understand the impact of various emission sources on regional air quality and community air pollutant exposure, and how policies can be designed to control them effectively. The five topics listed above all seem very important! Some other thoughts: • Wildfire activities are expected to increase under a warming climate. It is necessary to further investigate the air quality impacts of wildfires and reduce uncertainties in modeling fire smoke dispersion and the effectiveness of preventive measures. • Better understand the contributions of off-road sources (ocean-going vessels, aircraft, etc) to air quality and possible ways to mitigate their emissions (although it's hard to reduce emissions for these categories beyond CARB's jurisdiction). • It'd be interesting to investigate the short-term and long-term air quality impacts of autonomous vehicles in California.
AQ Academic Survey	With the lowering of the PM2.5 standard, we will need increased understanding of PM2.5 formation and loss throughout all seasons across California, including in large cities like Los Angeles and San Francisco, in the Central Valley and other more rural regions, as well as cities within the Central Valley like Bakersfield. This is likely best done with 1) adding in more speciated and total PM2.5 monitoring stations in key locations, especially for EJ concerns described below, to get seasonal and long-term information, and 2) also collecting data in shorter field intensives with more chemical information of gases and aerosols. Past campaign data has focused on the summer, so field intensives over the winter should be prioritized. Processes important for PM2.5 formation are different in the winter, and models have very little data for evaluation. Once the processes are better understood, we need to evaluate models and make improvements to ensure PM2.5 is accurately represented across all seasons.

AQ Academic Survey	Understanding key PM2.5 formation mechanisms: More research on secondary aerosol formation, including nighttime chemistry, aqueous-phase reactions, nocturnal residual layer dynamics, and VOCs-NOx-SO_2 interactions, is essential to refine the understanding of PM2.5 sources. Enhanced source apportionment through real-time PM speciation monitoring: Expanding monitoring networks and sub-hourly data collection will improve pollution tracking, enable more accurate source identification, and support more effective regulatory assessments. Wildfire emissions and air quality impacts: Improved data on wildfire smoke composition, transport, and atmospheric aging is crucial as wildfires become more frequent and prolonged. VOC and SVOC emissions: Improved measurement of VOCs and semi-volatile organic compounds (SVOCs) is needed to understand their roles in ozone and secondary PM2.5 formation.
AQ Academic Survey	PM2.5 formation and sources - Contribution of primary vs. secondary aerosols to PM2.5; Source apportionment of PM2.5 at higher temporal and spatial scales; Need long-term, real-time, speciated measurements of PM2.5 and VOC for process-level understanding of PM2.5 sources and formation (e.g., establish more ASCENT-like sites in CA but also with VOC measurements). Also, with secondary organic aerosols becoming an increasingly dominant fraction of PM2.5, need coordinated laboratory and ambient studies to understand their formation mechanisms with changing emissions and a changing climate. Linking chemical composition to toxicity and health effects, understand the toxicity of different PM2.5 components as well as their VOC precursors.

Air Quality – NAAQS in a Changing Climate

Source	Comment/Priority
AQ Academic Survey	Understanding the role of heat as a direct driver of emissions (e.g., from the urban or rural biosphere) and an indirect driver of emissions (e.g., by changes in human behavior), and strategies for managing heat (e.g., urban tree planting, white roofs) and their connection to GHGs and AQ. Changes in urban infrastructure (closing or repurposing refineries, gas stations, elimination of natural gas piping, electrification of embedded industries) and their effects on GHG emissions, AQ, EJ, and jobs.

AQ Academic Survey	No appreciable improvements have been seen in the design values of O_3 or PM2.5 since 2015 in any of the most polluted air basins in California. This observed fact contradicts all prior SIP modeling. Mounting evidence suggests that there are likely overlooked agricultural soil NOx emissions (as both NO and HONO) that are impacting air quality in many rural parts of the state. Wildfires are known to impact air pollution 1 in 5 days in the Central Valley during the warm season, and this effect is growing at an alarming rate, with a doubling time of 10-20 years. These sources are rapidly becoming the dominant air pollution concerns in the 21st century, and too much is uncertain about their overall emission amounts and timing. Both are very difficult to numerically model, and thus, emphasis should be placed on observational studies. Finally, the hemispheric background ozone concentrations dominate the ODV, and this source, primarily from stratosphere-troposphere exchange, needs to be studied.
AQ Academic Survey	Expectation of future AQ and climate implications (including PM, ozone, and CH_4) as wildfires increase and intensify; improved smoke transport models to facilitate increased use of prescribed fire to mitigate the size and severity of wildfires
AQ Academic Survey	Vertical profile measurements of O_3 and aerosol are critical for characterizing the amount of transported pollutants (stratospheric intrusions, long-range transport from Asia, wildfire plumes) that reach the surface (e.g., via turbulent mixing into the boundary layer) and may lead to NAAQS violations. These are pollutant sources that are largely uncontrollable by the State of California (with perhaps the exception of wildfires burning within California) and, therefore, quantifying their contribution to the pollution burden and potential NAAQS exceedances is important.

Air Quality – Volatile Organic Compounds

Source	Comment/Priority
AQ Academic Survey	Survey of ammonia, NOx, and methane emissions from agricultural sources across the state. Integration of surface and high spatiotemporal resolution satellite data via data fusion and/or data assimilation for assessing exposure. Greatly expanded capability for VOC measurements and/or an intensive field campaign focused on VOCs. Machine-learning-based model emulators for fast and accurate "what-if" scenario simulations.
AQ Academic Survey	CARB should support additional work to evaluate bottom-up inventories that serve as the basis for understanding both past changes and future efforts to improve air quality. Examples where additional effort would be helpful: How has and will the mix of VOCs in the South Coast Basin changed? Improvements are needed in monitoring biogenic VOCs, emissions from cooking, and non-mobile sources more generally. In the Central Valley, bottom-up emissions inventories

	from dairies and digestors need substantially more effort to evaluate against observations.
AQ Academic Survey	Process understanding for PM2.5 formation, particularly for the SJV in the winter season. These processes include oxidation and multiphase chemistry, and understanding boundary layer dynamics and its interaction with emissions and chemistry. Wildfire emissions, chemistry, and transport for PM2.5 and O_3 impacts require further research. The response of urban ozone and PM2.5 to continued reductions in NOx and VOC emissions, as well as sources of VOCs and potential for continued reductions, needs further study. Continued top-down analysis of emissions through satellite, aircraft, or ground-based observations to validate and refine inventories. Of particular interest will be sources of NOx from urban sources and soils.
AQ Academic Survey	Understanding key PM2.5 formation mechanisms: More research on secondary aerosol formation, including nighttime chemistry, aqueous-phase reactions, nocturnal residual layer dynamics, and VOCs-NOx-SO_2 interactions, is essential to refine the understanding of PM2.5 sources. Enhanced source apportionment through real-time PM speciation monitoring: Expanding monitoring networks and sub-hourly data collection will improve pollution tracking, enable more accurate source identification, and support more effective regulatory assessments. Wildfire emissions and air quality impacts: Improved data on wildfire smoke composition, transport, and atmospheric aging is crucial as wildfires become more frequent and prolonged. VOC and SVOC emissions: Improved measurement of VOCs and semi-volatile organic compounds (SVOCs) is needed to understand their roles in ozone and secondary PM2.5 formation.
AQ Academic Survey	PM2.5 formation and sources - Contribution of primary vs. secondary aerosols to PM2.5; Source apportionment of PM2.5 at higher temporal and spatial scales; Need long-term, real-time, speciated measurements of PM2.5 and VOC for process-level understanding of PM2.5 sources and formation (e.g., establish more ASCENT-like sites in CA but also with VOC measurements). Also, with secondary organic aerosols becoming an increasingly dominant fraction of PM2.5, need coordinated laboratory and ambient studies to understand their formation mechanisms with changing emissions and a changing climate. Linking chemical composition to toxicity and health effects, understand the toxicity of different PM2.5 components as well as their VOC precursors.

Air Quality – Dairy and Agriculture

Source	Comment/Priority
AQ Academic Survey	Survey of ammonia, NOx, and methane emissions from agricultural sources across the state.
AQ Academic Survey	No appreciable improvements have been seen in the design values of O3 or PM2.5 since 2015 in any of the most polluted air basins in California. This observed fact contradicts all prior SIP modeling. Mounting evidence suggests that there are likely overlooked agricultural soil NOx emissions (as both NO and HONO) that are impacting air quality in many rural parts of the state. Wildfires are known to impact air pollution 1 in 5 days in the Central Valley during the warm season, and this effect is growing at an alarming rate, with a doubling time of 10-20 years. These sources are rapidly becoming the dominant air pollution concerns in the 21st century, and too much is uncertain about their overall emission amounts and timing. Both are very difficult to numerically model, and thus, emphasis should be placed on observational studies. Finally, the hemispheric background ozone concentrations dominate the ODV, and this source, primarily from stratosphere-troposphere exchange, needs to be studied. Disadvantaged communities in rural agricultural areas throughout the Salinas, San Joaquin, Eastern Coachella, and Imperial Valleys disproportionately bear the impacts of poor air quality. The research outlined above regarding the emissions that are most impacting these rural and impoverished communities will serve the mission of environmental justice.
AQ Academic Survey	CARB should support additional work to evaluate bottom-up inventories that serve as the basis for understanding both past changes and future efforts to improve air quality. Examples where additional effort would be helpful: How has and will the mix of VOCs in the South Coast Basin changed? Improvements are needed in monitoring biogenic VOCs, emissions from cooking, and non-mobile sources more generally. In the Central Valley, bottom-up emissions inventories from dairies and digestors need substantially more effort to evaluate against observations.
AQ Academic Survey	Emissions inventories for agricultural activities may not be sufficient to understand future changes due to changes in activities and a lack of process-based, predictive, proven models. While this sector will likely become the source of an increasing fraction of emissions in CA, it is likely less well understood compared to others. These emissions impact both wintertime and summertime PM and O_3. Recommend studies/activities which can inform future Ag-related emissions and their impacts on air quality and climate gas emissions. Can current geostationary satellites (TEMPO) be used to sufficiently monitor EJ concerns, or is higher spatial resolution needed, or different species? What tech is needed for monitoring?

AQ Academic Survey	Pollution control policies have led to significant reductions of PM2.5 through the mitigation of precursors such as nitrogen oxides (NOx) and anthropogenic volatile organic compounds (VOCs); however, both natural and anthropogenic emissions of ammonia (NH_3) continue to contribute to PM2.5 globally. Sources of NH_3 in the troposphere include biomass burning and emissions from livestock waste, large-scale application of fertilizer, automobile emissions, and, to a lesser extent, industrial processes. Agricultural sources (e.g., crop fertilizer and livestock manure) contribute to over 57% of global NH_3 emissions, dominate NH_3 emissions in California, and are an important topic to be considered by the California Air Resources Board (CARB).
AQ Academic Survey	Process understanding for PM2.5 formation, particularly for the SJV in the winter season. These processes include oxidation and multiphase chemistry, and understanding boundary layer dynamics and its interaction with emissions and chemistry. Wildfire emissions, chemistry, and transport for PM2.5 and O3 impacts require further research. The response of urban ozone and PM2.5 to continued reductions in NOx and VOC emissions, as well as sources of VOCs and potential for continued reductions, needs further study. Continued top-down analysis of emissions through satellite, aircraft, or ground-based observations to validate and refine inventories. Of particular interest will be sources of NOx from urban sources and soils.
Health Academic Survey	Many of the air quality impacts are based on urban-level measurements. We need to understand more science of rural area air quality impacts from agriculture and natural phenomena like the Salton Sea, Owens Valley Lake, Tulare Lake, and others. The parameters and sampling methodology that are often applied to rural areas are taken from methods used in urban areas. We need more specific method development for rural areas.

Air Quality – Reducing Disparities

Source	**Comment/Priority**
Public meeting	San Bernardino County faces significant air quality concerns, including a “Grade F” for air quality according to the American Lung Association’s State of the Air. Air pollution is linked to preterm births, low birth weight, and stillbirth. SB’s valley location also makes it susceptible to thermal inversion, where air pollution is often trapped within the valley. Poor birth outcomes and high infant mortality rates. What are the specific pollutants and sources contributing to poor air quality in San Bernardino County, and how can regulatory measures effectively mitigate their impact on perinatal outcomes?

AQ Academic Survey	Research supporting EJ goals must include opportunities for public learning that can be generalized. Too much EJ research today is siloed and offers insufficient opportunity for learning to become embedded in air quality models or to be applied in similar EJ settings that are not the direct subject of an individual study. Open access to observations should be a cornerstone of all ARB-funded projects, including EJ ones. Models should be developed that are faithful to our understanding and accessible to the EJ community. Machine learning and other new data science tools make this possible (with some research and focused effort)
AQ Academic Survey	With the proliferation of low-cost sensor networks, there is a growing need to develop advanced spatial interpolation and data fusion algorithms. These innovations will enable the generation of high-resolution exposure maps for air pollutants of interest, which can inform targeted reduction strategies for disadvantaged communities.
AQ Academic Survey	Research to support the development of inventories and AQ modeling at EJ scales. See https://crcao.org/wp-content/uploads/2023/03/2022-CRC-AQRN-Workshop-Summary.pdf
AQ Academic Survey	Integration of surface and high spatiotemporal resolution satellite data via data fusion and/or data assimilation for assessing exposure. Machine-learning-based model emulators for fast and accurate "what-if" scenario simulations. Collaboration with social scientists to understand the social and political drivers of decision-making relevant to disparities in AQ exposure.
AQ Academic Survey	Disadvantaged communities in rural agricultural areas throughout the Salinas, San Joaquin, Eastern Coachella, and Imperial Valleys disproportionately bear the impacts of poor air quality. The research outlined above regarding the emissions that are most impacting these rural and impoverished communities will serve the mission of environmental justice.
AQ Academic Survey	Understanding actual exposures in a variety of settings is important. This includes not only outdoors but indoors, including inside and outside (i.e., non-exhaust emissions) vehicles. It also includes high-resolution measurements in disadvantaged communities to identify local sources that may be small enough to "fly under the radar" but have significant impacts. To do this, the development of small, portable, and RELIABLE sensors for a variety of air pollutants and climate gases needs to be developed, analogous to the Purple Air monitors for PM. Measuring individual metals and VOC would be great, in addition to the usual criteria pollutants. And data from them needs to be widely available, as with Purple Air. If communities had access to reliable data that could be used to pinpoint sources and monitor their own air quality, it would be a big step forward.
AQ Academic Survey	Improved assessment of emissions from roadways and ports.

AQ Academic Survey	Can current geostationary satellites (TEMPO) be used to sufficiently monitor EJ concerns, or is higher spatial resolution needed for different species? What tech is needed for monitoring?
AQ Academic Survey	Evaluation of the possible role of low-cost sensors (both PM and trace gases), determination of required data quality and uncertainty to be useful in reaching future goals, and development of needed calibration and QA/QC procedures.
AQ Academic Survey	Research supporting point-source emission characterization by deploying and analyzing mobile monitoring networks or downscaling satellite datasets is of great importance to determine small-scale PM and PM precursor sources that might affect underrepresented communities.
AQ Academic Survey	Improving the identification, quantification, and tracking of emission sources and exposure is crucial for advancing EJ goals. This requires investing in projects that develop and demonstrate more affordable, compact instruments capable of high-resolution speciation measurements for both PM and gases, which can help detect and track previously hard-to-identify pollution sources. These instruments should be designed for long-term, unattended deployment to enable widespread coverage in impacted communities. Additionally, leveraging advanced satellite remote sensing provides a more spatially comprehensive assessment, facilitating the identification and tracking of pollution sources, supporting the detection of exposure and health disparities, enabling the evaluation of progress in reducing exposure, and distinguishing between local and regional sources and hotspots that affect EJ communities.
AQ Academic Survey	Incorporation of new geostationary satellite data into pollutant distribution analysis. The use of sensor networks to fill in the gaps between the regulatory monitor network, together with a better understanding of the data quality and utility of these sensor networks. Higher resolution observations from mobile platforms or citizen science to characterize pollutant distributions Social science/community outreach to foster understanding of air quality issues within communities and take community input to improve perception of air quality.
AQ Academic Survey	Better understanding of the spatial distribution of air pollutants from different sources and quantifying the injustice • Developing high-resolution emissions inventory and modeling capabilities • Employing multiple observational data sources to refine the resolution of pollutants Solicit the concerns of communities. I think some of them are concerned about toxics more than the criteria air pollutants. But our understanding of air toxics is limited.

AQ Academic Survey	Research on methods based on comprehensive measurements and modeling to determine the cumulative impacts of all sources in a region on chronic air toxics health risks and health risks due to criteria pollutants throughout the region. Methods like those used in South Coast AQMD MATES studies can be used to determine disproportionate impacts, which is necessary to support EJ goals. But the methods used in MATES are associated with systematic errors in model data, which make it difficult to draw conclusions about neighborhoods that are disproportionately impacted. Both modeled and measured data also need to include a more comprehensive suite of compounds. Research is needed to improve programs like MATES to provide data on disproportionate cumulative impacts with errors small enough to support decision-making.
AQ Academic Survey	When considering the location of new monitoring stations to add speciated and total PM2.5 observations, CARB should prioritize regions without these measurements with a focus on ensuring communities that are historically underrepresented have adequate monitoring stations. While filling in these gaps with low-cost sensor approaches is very useful to understand fine-scale features, regions with different chemical regimes should still have a speciated and total PM2.5 monitoring station. Low-cost sensors are difficult to use for improving process-level understanding, which is needed for source apportionment studies. Improved modeling at finer resolution should also be prioritized by CARB to investigate air pollution at neighborhood scales and used to inform policy. Ensuring that modeling and observational studies address rural communities as well as communities impacted by wildfires, including wildfire fighters, should also be prioritized.
AQ Academic Survey	More localized monitoring of not just PM mass concentrations, but also chemical composition and physical properties, is needed to understand and address air quality disparities in disadvantaged communities.
AQ Academic Survey	Investigating sources of local vs. regional pollution and develop targeted mitigation strategies, conduct follow-up studies to assess the effectiveness of the implemented strategies; It appears that CARB has supported various research aimed at reducing air quality disparities, (if this has not been done before) it may be useful to conduct a comprehensive analysis to evaluate the effectiveness of various mitigation strategies and identify what work the best, to aid in the planning of future research.

Climate – Natural and Working Lands

Source	**Comment/Priority**

Public meeting - Breakout room survey	What research needs to be done to ensure that any project carried to production scale will actually result in zero or negative carbon emissions? For example, right now, there are too many “renewable hydrogen projects” being brought online to take advantage of federal 45V tax credits that are exacerbating the climate crisis, e.g., blue hydrogen. We cannot afford to listen to the fossil fuel industry on how to fight climate change. They are the problem, and not part of the solution. A particular area needing significant research is in effective direct air capture of CO_2. We will need to do this on a gigaton/year scale in the 2030s, as we will likely have exceeded 2 degrees C of global warming by then. I am planning to write a research proposal on this by the Apr 10 deadline.
Public meeting - Breakout room survey	Characterization and map of wetland methane in California (quantities, concentrations, locations) How can we tap wetland methane for power or mitigate emissions if not?
Public meeting - Breakout room survey	What are the concentrations, volumes, and locations of wetland methane? Can we mitigate those emissions or tap them for power?
LERN Workshop	Impact and importance of natural environments. Preserving open space (trees and healthy soils), carbon sequestration. What are the co-benefits and case studies demonstrating these are viable strategies to pursue?
LERN Workshop	The impact of natural environments. Preserving open space (trees and healthy soils), carbon sequestration. What is the impact and the importance of that? Also, to cool communities? Unsure if we know enough to convince people that this is a viable strategy to pursue.
Public survey	It is possible to capture solar energy without using the current areas that require solar panels, since this implies a large, deforested area. The research would be to identify how trees vertically capture the greatest amount of solar energy to be used for their needs.
AQ Academic Survey	Changes in urban infrastructure (closing or repurposing refineries, gas stations, elimination of natural gas piping, electrification of embedded industries) and their effects on GHG emissions, AQ, EJ, and jobs. Tracking changes in GHG emissions with low latency (e.g., quarterly reporting), spatial and sectoral mapping of the emissions, and explicit reporting on the efficacy of state and local objectives against publicly described targets, allowing policy to be reset quickly if we are falling behind the goals.

Climate – Greenhouse Gas Measurements at Relevant Scales

Source	**Comment/Priority**

LERN Workshop	SB 1383 compliance specifically in multifamily dwellings to reduce landfill methane emissions.
AQ Academic Survey	A better understanding of sources of methane emissions is needed to identify potential ways to reduce emissions. Identification of potential sensitive subpopulations that may need additional risk messaging, e.g., pregnant people, specific life stages, that are not targeted with the current messaging. As society continues to transition to a net-zero future, and as communities invest in adaptation and resilience, CARB may also need to evaluate the protectiveness of air quality policies under different scenarios, accounting for both co-benefits and unintended negative consequences, e.g., emissions from mining of critical minerals.

Climate – Wildfire

Source	Comment/Priority
LERN Workshop	How are fires countering the reduction achievements for air quality and climate emissions?
LERN Workshop	In the Truckee Tahoe area, we have challenges with wildfire risk. We want to utilize some of this fuel to offset heating costs and electricity by using biomass facilities. Biomass permitting is a huge challenge for us due to the air quality concerns. However, their emissions are significantly less than wildfires and less than controlled burns. Provide public information on the pros and cons of biomass plants vs wildfire emissions and controlled burn emissions, and emissions of long-range transport.
LERN Workshop	Rural communities (Napa County, some rural sections, and rural-urban interface). One concern mentioned a lot is, even if we are implementing a lot of our climate action strategies well, how fires counter all our reduction achievements.
Climate Academic Survey	Wildfire emissions--from wild and working lands--will be important seasonal and uncontrolled carbon emissions on short- to medium time scales and will be among the most challenging air pollutants and health concerns in many settings (especially in many beleaguered communities). A better understanding of the impacts of widespread wildfires on water resources (including quality) is needed.
Climate Academic Survey	Reduction of poor air quality, equity metrics for emission reductions, wildfire and EJ outcomes data, community engagement, as well as distributive and recognitional outcomes/metrics for implementation and evaluation.

Climate Academic Survey	Climate change is accelerating a transformation in wildfire behavior across California landscapes. Increasing fire frequency and intensity can lead to a broad array of changes to fire emissions that are not yet well understood. Because these changes occur under the most extreme fire conditions, limited measurements can be taken in the field, and those that are often taken don't mimic future fire behavior. A scaled laboratory approach paired with modeling of potential fire conditions could fill these gaps to understand fire emissions under changing fire regimes and behavior. A steady-burning apparatus already used in studies of WUI fuels can repeatably study emissions from plant species across California under different moisture, smoldering/flaming, wind, oxygen, and heating conditions, which, paired with fire modeling, can be designed to mimic a broad array of potential future fire scenarios. Effluents, including GHGs, PM, VOCs, etc., can be sampled and projected for different fire scenarios.
Climate Academic Survey	Disadvantaged communities are heavily affected by wildfire smoke, yet they often don't have the means to take preventive actions. Understanding and reducing potential exposure to these communities is essential. One of the most effective means of landscape-scale emissions and risk reduction is prescribed burning, yet these efforts also produce local emissions. One of the biggest unknowns in these studies is fuel consumption, the fraction of fuel that actually burns in a fire. Models such as FOFEM estimate the fraction of fuel burned, but these calculations do not distinguish the intensity of burning, only the fuel type and smoldering or flaming conditions. Laboratory studies show a wide range of behaviors that may play an even larger role than EF in affecting net smoke and GHG emissions. Multi-scale experiments, measurements, and modeling are necessary to close this gap and add the influence of weather, moisture, and fire behavior conditions into these calculations.
Climate Academic Survey	Wildfires in California are impacting communities more than ever before, with tens of thousands of homes and other structures lost, and trends increasing. Estimating emissions from these fires is essential for health and GHG estimates. The first project by CARB measuring emissions from these fires is underway and will provide a wealth of data; however, the ongoing study will be limited to new construction ADUs without consideration of older structures, diverse materials, vehicles, and other surrounding fuels that burn and contribute effluents. A wide-ranging study is needed to characterize emissions of all fuels present in the WUI and an assessment of their prevalence in different communities and structure types. Controlled laboratory measurements are well-suited to this effort in order to cost-effectively evaluate a wide range of materials and then build this information into models for different structures.

Climate Academic Survey	Disadvantaged communities are significantly burdened by wildfire losses and are also less able to prevent exposure to toxic emissions from these fires. When communities burn, a wide range of pollutants are released that we are just starting to understand. Both for health and toxic effects, as well as to better understand these fires' contribution to GHG emissions, it is critical to develop a wider view of the particulate and gaseous emissions from all materials present in the Wildland-Urban Interface. A laboratory study using a controlled burning apparatus is ideal to accomplish this, as there are so many potential materials to study, document, and eventually combine into fuel models for different structures and WUI areas. These results can be combined with larger-scale and field measurements to build combined models for the majority of fuels in a WUI area to better understand emissions.

Climate – Equity and Just Transition

Source	**Comment/Priority**
Public meeting - Breakout room survey	Determine the level of emission reductions needed to come from local action to meet CA climate goals (and which roles local governments can play best). Develop statewide data tools/portals for energy and VMT data. Conduct a statewide inventory of emissions by jurisdiction and map overlaying: Emissions, Wildfire risk, DACs (to help with action/funding prioritization). Research opportunities and gaps to fund key priority local emission reduction measures
LERN Workshop	On adaptation: • Alleviating extreme heat with holistic solutions. • Green infrastructure/flood protection/wildfire risk reduction/groundwater recharge. • Circular Bioeconomy Systems utilizing municipal infrastructure, such as products and energy from wastewater treatment facilities and solid waste facilities. How can urban food forests help to address food insecurity while also addressing heat islands and carbon sequestration?
LERN Workshop	Learn and better understand the true impact of green hydrogen. Hear this is the solution, and then hear, no, it's horrible when you combust it, and it harms the sources where it's being burned for energy. Want to better understand that because people seem to be all over the map.
LERN Workshop	How does locating polluting industries in disadvantaged communities create a Carbon Leakage Effect? They're less regulated than if they were in wealthy communities.

AQ Academic Survey	Better understanding of sources of methane emissions is needed to identify potential ways to reduce emissions. Identification of potential sensitive subpopulations that may need additional risk messaging, e.g., pregnant people, specific life stages, that are not targeted with current messaging. As society continues to transition to a net-zero future, and as communities invest in adaptation and resilience, CARB may also need to evaluate the protectiveness of air quality policies under different scenarios, accounting for both co-benefits and unintended negative consequences, e.g., emissions from mining of critical minerals.
AQ Academic Survey	Assessments of interventions to reduce air quality disparities are still needed (less need to simply identify disparities). Also important to consider cumulative impacts across media, and to evaluate how climate change will impact disparities, including through migration and climate gentrification.
Climate Academic Survey	Actions and measures around community engagement, particularly from environmental justice communities, participatory metrics, distributive outcomes, and recognitional ones. Another area, we need help is cumulative impacts related to multiple and various impacts of environmental justice. We also need metrics on climate adaptation - and the vulnerabilities and impacts of achieving these goals.
AQ Academic Survey	Changes in urban infrastructure (closing or repurposing refineries, gas stations, elimination of natural gas piping, electrification of embedded industries) and their effects on GHG emissions, AQ, EJ, and jobs. Tracking changes in GHG emissions with low latency (e.g., quarterly reporting), spatial and sectoral mapping of the emissions, and explicit reporting on the efficacy of state and local objectives against publicly described targets, allowing policy to be reset quickly if we are falling behind the goals.

Mobile Sources – NOx and Greenhouse Gas Emissions

Source	**Comment/Priority**
Mobile Sources Academic Survey	Life cycle assessment of BEV vs. FCEV pathways today and in the future, considering CA grid electricity decarbonization policy and expected clean H_2 production pathways. Include potential impacts of hydrogen leakage, water use, land use, and embodied carbon emissions for vehicle manufacturing. Research the potential emission reduction and cost impacts if hydrogen use for CA refineries were transitioned to clean hydrogen. Improve understanding of ZEV truck travel and refueling patterns as public access ZEV infrastructure is built out through federal and state funding.

Mobile Sources Academic Survey	EPA has indicated a desire to investigate the impact of commanded enrichment on emissions of vehicles. CARB could partner with the EPA to investigate appropriate vehicle-specific power emission factors when commanded enrichment is being engaged. This information would support future updates to EMFAC and MOVES, as well as potential rulemaking on limiting commanded enrichment practice. This type of requirement is now in effect in Europe. Tracking indicators of the pace of electrification and its enablers, such as infrastructure, grid capacity, and technology/material availability.
Public meeting	How do we get rid of high emitters more quickly?

Mobile Sources – Advanced Monitoring

Source	**Comment/Priority**
Mobile Sources Academic Survey	Now that vehicles are going to be required by Clean Truck Check to share data with CARB on vehicle health via OBD and/or opacity measurements, a research project to collate this data and determine the failure/repair rate and impact on fleet emissions as more of the fleet is required to comply. This will augment the legacy roadside measurement studies, such as the Caldecott Tunnel plume sampling.