Planned Research

Fiscal Year 2014-15

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California Environmental Protection Agency
Air Resources Board

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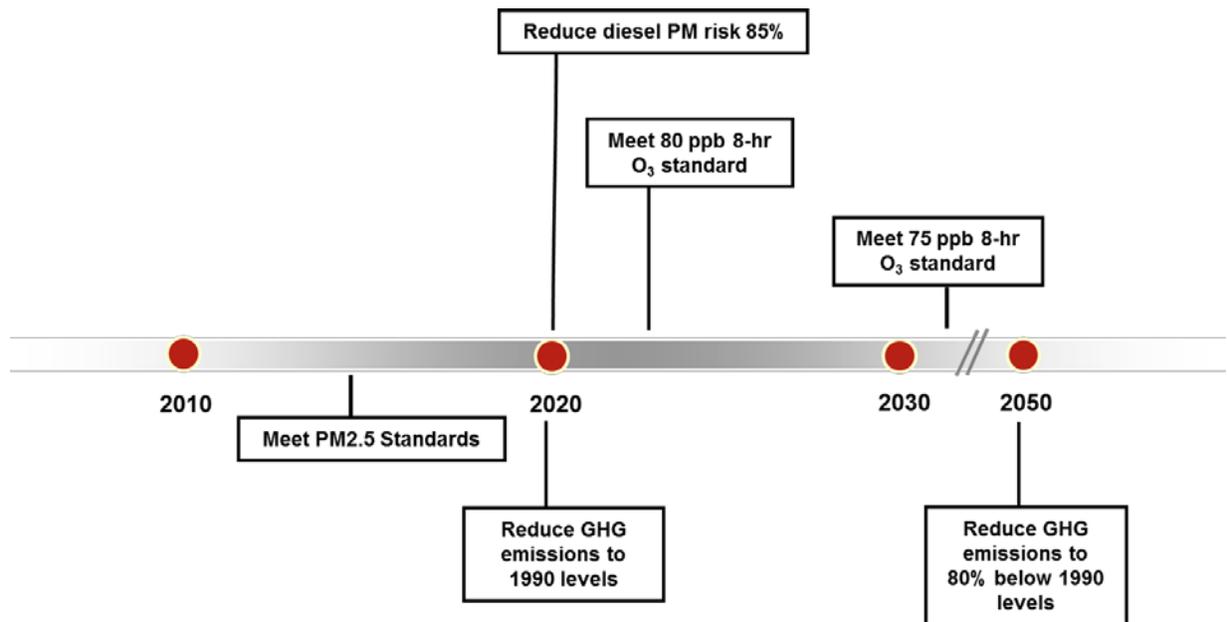
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INTRODUCTION

The goal of ARB's research program is to provide timely scientific and technical information to help the Board, local air districts, and others take effective actions to improve air quality and meet greenhouse gas reduction goals. ARB's research on the health effects of air pollution focuses on emerging issues of importance to California communities. Improving the understanding of transportation-related air pollution exposures continues to be a high priority. The climate change research program supports the development of greenhouse gas mitigation strategies, and investigates the societal impacts of actions taken.

ARB's research program will continue to play an important role in meeting the challenges of increasingly stringent federal air quality standards and long-term climate goals. California is planning for the future by assessing what it will take to meet federal deadlines for national air ambient air quality standards (NAAQS), reducing community health risk from air pollution, and meeting greenhouse gas reduction goals in 2020 and beyond. The projects outlined in this Plan will provide essential data and tools to support action to meet these climate and air quality goals. The projects are designed to provide answers to near-term questions that are important for program implementation and to explore the benefits of longer-term strategies.

Figure 1. California's key air quality and climate change milestones through 2050.

The Fiscal Year 2014-15 Research Plan includes 14 research concepts, requiring approximately $5.3 million in funding. As shown in Figure 2, funding is allocated to research related to health (33%), air quality (30%), and climate change (37%).

Proposed Funding Allocation for
Fiscal Year 2014-15

Health, $1,750,000

Air Quality, $1,600,000

Climate Change, $1,950,000

Figure 2. Proposed ARB research funding allocation for Fiscal Year 2014-15.

PLANNING PROCESS

This research plan is designed to address the Board's highest priority program needs. The strategic planning process used to develop the Annual Research Plan begins with feedback from ARB program staff on the Board's regulatory priorities and challenges. Both near-term and longer-term needs are assessed. Project ideas are also solicited through an online public submission process. Projects are then developed through extensive discussions with ARB program staff and experts from research institutions and other State and federal agencies. Projects are carefully reviewed by ARB staff and the Research Screening Committee for scientific rigor, policy relevance, and strong links to ARB's programs and mission. A proposed Plan is presented to the Board and, if approved, full research proposals are developed through a solicitation which recognizes the academic assets of the University of California and California State University systems. Draft proposals are evaluated by technical review teams that include partners from federal and other State agencies as well as air districts. The developed projects are then brought back to the RSC and the Board to request approval for funding of each project.

COORDINATION, LEVERAGING, AND COLLABORATION

Research coordination with other State agencies, federal agencies, air districts, and research institutions is also an important aspect of outreach in order to avoid duplication of effort, to leverage funding, to identify opportunities for collaborative efforts, and to maximize the utility of research results. ARB staff seeks co-funding opportunities and explores other ways to leverage limited research dollars. This process enables ARB to participate in projects and studies outside the reach of ARB's research budget alone; recent examples of this type of collaboration include ARB's involvement with the Air

Quality Applied Sciences Team (National Aeronautics and Space Administration [NASA]) and the Los Angeles Megacities project (funded by the National Institute of Standards and Technology [NIST]).

To promote coordination, information is shared at all stages of the research process, from project development to updates on research progress and final reports. Other activities include participation in interagency groups, such as the Climate Action Team (CAT) Research Working Group and the Transportation Research Roundup. In the development of the research topics included in this plan, ARB staff coordinated with numerous State and federal agencies and partners, including federal agencies spanning the United States Environmental Protection Agency (U.S. EPA), the Department of Energy, the Department of Transportation, the National Highway Traffic Safety Administration, the National Institute of Environmental Health Sciences; other State agencies including the Governor's Office of Planning and Research, the California Energy and Public Utilities Commissions, the California Department of Transportation (Caltrans), the Office of Environmental Health Hazard Assessment, Housing and Community Development, the Strategic Growth Council; and local air districts and non-governmental organizations such as the Health Effects Institute (HEI) and the Coordinating Research Council. Example areas of interagency research collaboration include agricultural emissions, zero emission vehicles, and alternative fuels.

ARB staff communicates new research results to the public through seminars, press releases, final reports, and updates at Board Meetings. ARB staff also co-sponsor workshops with other State agencies on a variety of research topics. The workshops provide a public setting for researchers funded by multiple State agencies to showcase their efforts, provide an opportunity for an in-depth discussion of the implications of their results, and identify remaining research gaps.
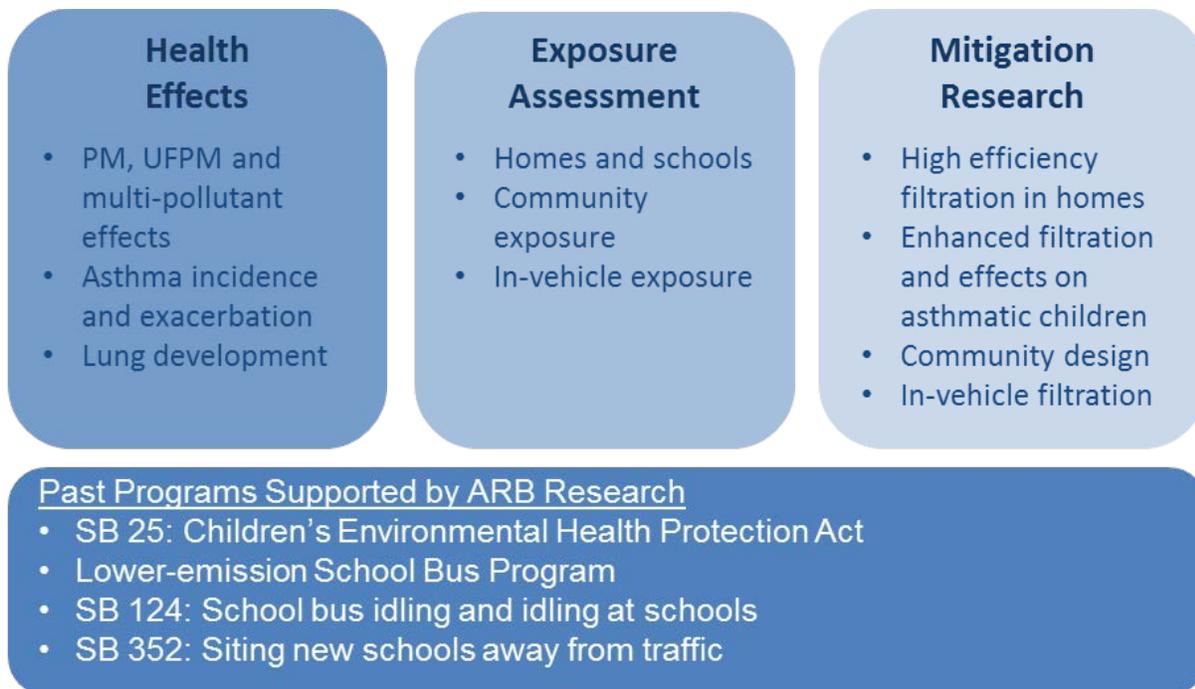
HEALTH

Current Research

ARB research projects are currently investigating a number of established and emerging health-related issues. One example is the issue of multi-pollutant exposures, which are typical for ambient air. Single pollutant studies have been essential to the process of establishing health protective levels for NAAQS. Understanding how concurrent exposure to ozone and PM2.5 may affect public health is the focus of a FY 2013-14 research project now underway.

The research program continues to quantify the degree to which vulnerable groups are more sensitive to air pollution impacts and is exploring new ways to study vulnerability, such as examining the impact of genetic variability on health in populations exposed to different sources of air pollution. For example, a current ARB-funded study of elderly subjects with cardiovascular disease in Los Angeles is designed to provide information on the effects of air pollution exposures from difference sources on the expression of genes related to the pathophysiological mechanisms of PM2.5. The results will be available in the spring of 2014.

Near-roadway and ultrafine particulate matter (UFPM) exposures continue to be research priorities. A study with rodents that was completed earlier this year investigated the cardiovascular effects from exposure to UFPM. The study results showed that the organic constituents of UFPM contribute to the development of atherosclerotic plaques in the arteries. A current study of asthmatic children is examining the impacts of primary and secondary organic aerosols to determine the relationship of these components of PM2.5, including UFPM, to asthma exacerbations. Another study is evaluating the impacts of sound wall/vegetation combinations on downwind levels of traffic-related pollution including PM2.5, ultrafine particles, black carbon, and oxides of nitrogen. These studies will shed light on toxicity and mechanistic pathways and potentially useful mitigation measures that can be developed to reduce roadway exposures. Results from these research projects are expected in 2015 and 2016.

To support ARB's environmental justice policies, researchers are updating, automating, and expanding the ARB funded Environmental Justice Screening Method (EJSM) to cover the entire State. Use of the most current data sets will allow provide for better capture patterns of cumulative impact and vulnerability of importance to environmental justice communities Statewide. This effort will enhance the understanding of the geographic patterns of cumulative impacts and vulnerability, including data limitations and gaps, and will provide valuable information to support environmental justice programs, initiatives, and policies.

Overall, the ARB health research program has components that explore the health effects of air pollution, environments with higher exposures, and mitigation opportunities.

Health Effects
- PM, UFPM and multi-pollutant effects
- Asthma incidence and exacerbation
- Lung development

Exposure Assessment
- Homes and schools
- Community exposure
- In-vehicle exposure

Mitigation Research
- High efficiency filtration in homes
- Enhanced filtration and effects on asthmatic children
- Community design
- In-vehicle filtration

Past Programs Supported by ARB Research
- SB 25: Children's Environmental Health Protection Act
- Lower-emission School Bus Program
- SB 124: School bus idling and idling at schools
- SB 352: Siting new schools away from traffic

Figure 3. Selected components of ARB's health research program. ARB-funded research projects have added to the body of evidence on the health impacts of exposure to air pollutants, especially particulate matter and ozone. The highly cited Children's Health Study in the 1990s provided new information on how air pollution affects children's health and development, and set the stage for epidemiologic studies of other vulnerable populations, for toxicological studies, exposure studies, and for investigations on potential mitigation approaches.

FY 2014-15 Research Focus

The health research emphasis for FY 2014-15 is to better understand the health impacts of UFPM, specifically looking at premature death and neurodegenerative disease. Another project is to develop a standardized approach to toxicological screening assays used in assessing the potential toxicity of different fuels and engine technologies. The third project focuses on indoor air exposures by investigating the potential exposure and health risk from formaldehyde, a toxic air contaminant, from fiberglass particle filters used in home heating and cooling systems.

Proposed Projects

- Association between Long-Term Ultrafine Particulate Matter Exposure and Premature Death
- Exposure to Ultrafine Particulate Matter and Neurodegenerative Disease
- Protocol Development for Particulate Matter Sample Preparation for Toxicity Testing
- Reducing Formaldehyde Emissions from Home Central Heating and Air Conditioning Filters

Association between Long-Term Ultrafine Particulate Matter Exposure and Premature Death

This project will fill the need for a sound epidemiological study on the health effects of long-term exposure to ultrafine particulate matter (UFPM), focused on the risk of premature death. There is a large body of literature showing that fine particulate matter (PM2.5) is associated with premature death, with the most persuasive evidence coming from long-term epidemiological studies. No comprehensive epidemiological study exists for UFPM, though some published research suggests that UFPM may pose a relatively greater health risk than PM2.5. While PM2.5 pollution in California, which includes an ultrafine component, is decreasing, the health risk associated with UFPM exposure is unknown. This research project is expected to lead to a clearer understanding of the health effects of exposure to UFPM, including health risk at ambient air concentrations.

Background: ARB, U.S. EPA, and others have funded toxicological and animal studies on the health effects of UFPM exposure, which have shed light on the potential mechanisms and pathways by which these particles can affect human health. Significant findings in these studies include evidence of cardiovascular effects in animals and humans. Although some UFPM epidemiologic studies have been published, the results are inconsistent, and the studies lacked adequate exposure assessment at the regional level.

Methods: The ambient concentrations of UFPM in California show strong spatial gradients, which have not been adequately characterized by monitoring at the regional level. This research proposal addresses this challenge using a combination of modeling and air monitoring. This project will also pair the ambient concentrations of UFPM with an existing epidemiological cohort. The U.S. EPA funded a research grant to UC Davis to conduct UFPM modeling research which is close to completion. The UC Davis team modeled UFPM concentrations, but there was not time to adequately verify the results with monitoring data. This proposed project will build on these preliminary findings by verifying the modeling results with monitoring data, and modifying the model based on UFPM measurements. This proposal has four parts: 1) a model that will provide daily and annual average concentrations of UFPM at various representative sites Statewide; 2) full validation of the model through comparison of its output with historical data; 3) an assessment of the Statewide UFPM concentrations via monitoring; and 4) an epidemiological study with an existing cohort to calculate the relative risk of premature death and other health endpoints from long-term exposure to UFPM.

Budget: $800,000

Exposure to Ultrafine Particulate Matter and Pathogenesis of Neurodegenerative Disease

This project will determine whether long-term exposure to ultrafine particulate matter (UFPM) is associated with the development of neurodegenerative processes and related cognitive deficits. Emerging evidence suggests that environmental factors, including exposure to air pollutants such as UFPM, may play a role in neurodegenerative diseases (ND) such as Alzheimer's and Parkinson's disease. These conditions primarily affect the elderly. The cause of these disorders is not understood,

and genetic factors alone seem insufficient to explain their prevalence. UFPM is an important size fraction to examine because several reports in the literature have shown that these small particles are transported directly into the brain.

Long-term UFPM exposures will be conducted in a rodent model of neurodegenerative disease, and cognitive behavioral outcomes will be related to subjects' age and duration of exposure. Neurodegenerative diseases are characterized by the progressive decay of structure and function of nerve cells, and associated declines in cognitive performance. The first question to be addressed is whether UFPM exposure causes adverse changes in cognitive function that increase with subjects' age and duration of exposure. The second question is whether UFPM exposure activates the central nervous system's immune response which is believed to be an early stage in the neurodegenerative process.

Background: Very little is known about the mechanisms by which exposure to air pollutants leads to neurodegenerative outcomes. Findings from several epidemiologic and animal studies suggest associations between exposure to ambient air pollution (such as traffic pollutants or black carbon) and cognitive declines. Evidence of diffuse amyloid plaques has been found in children and young adults exposed to high levels of air pollution in Mexico City. This is a sign of neurodegeneration resembling early stages of development of Alzheimer's disease. Other studies have shown that inhaled UFPM can travel directly to the brain via the olfactory nerve and that UFPM exposure can lead to increased levels of pro-inflammatory markers in the brain. Chronic inflammation may lead to neuronal damage and nervous system dysfunction.

Numerous animal models of neurodegenerative disease have been developed to demonstrate various facets of the disease and associated cognitive deficits, such as declines in spatial learning and memory. A number of rodent studies have shown changes in learning, memory, and behavior in response to air pollutant exposures, with some showing symptoms parallel to those observed in human patients. Previous studies have not focused on combining animal neurodegenerative models with air pollution exposures.

Methods: The exposure study will use rodents since they have been successfully used in both PM2.5 and UFPM neurotoxicity studies. Researchers can choose from a number of animal models that have been used over the last decade in neurological studies, due to their ability to display plaques, tangles, synaptic loss, neuronal loss, or even cognitive deficits. Changes in cognition to be studied may include deficits in spatial learning and memory. To test for immune responses, the researchers will examine markers of chronic neuroinflammation. Other indicators of neurodegenerative disease, such as the deposition of β-amyloid, should be evaluated.

Budget: $500,000

Protocol Development for Vehicle Emission Toxicity Testing for Particulate Matter

This project will develop a recommended standard operating protocol (SOP) for fine particulate matter (PM2.5) toxicological assays used as a screening tool for assessing

relative health risk of engine technologies and fuels. Standard toxicological assays of PM emissions have been used as a screen by ARB as one method of ensuring that no unintended adverse health effects result as new engine technologies and fuels come into use. While these assays are based on established procedures in the literature, there is no SOP for sample preparation for these assays. The lack of an SOP has introduced uncertainty and sample variability even within the same study, and has limited staff's ability to compare results between past and current studies. This will continue to be an issue for future study evaluations unless methodologies are better aligned through use of an established SOP. To the extent possible, the research will compare the recommended protocol with previously used procedures to assist ARB in interpreting the toxicity results from past studies.

Background: ARB has evaluated the toxicity of PM2.5 in numerous studies including those involved with engine emissions testing, indoor air pollutants, and concentrated ambient air pollutant samples. Due to the lack of an SOP, individual researchers have used different methodologies for PM2.5 sample preparation which can affect the inherent toxicological properties of the sample. Toxicological variations arise from the different physical and chemical interactions that occur during processing which can preserve some critical PM2.5 components, eliminate others, and possibly introduce artifacts that could lead to false positive results. While possibly acceptable for comparison of samples for a particular assay, the different processes used for PM2.5 sample preparations have compromised the ability to directly compare the toxicity of samples from different researchers even for the same PM2.5 sample. For example, in a recent study, one researcher evaporated the sample extraction solvent before toxicological testing while another used the solvent extraction directly. It is not known if the evaporation removed critical PM2.5 components or if using the solvent extraction directly introduced toxicological artifacts making result comparisons difficult. Best practices for sample preparation are needed, and there has not been a comprehensive evaluation of the merits of the various procedures.

Methods: Researchers will evaluate commonly used procedures for PM2.5 sample preparation, assess the relative merits, and recommend a standard operating protocol for assays used for PM2.5 toxicity of vehicle emissions. In developing a recommended SOP, researchers will consult with agencies and academics with relevant experience. The evaluation should focus on which procedures are the best at protecting sample chemical integrity, retaining the most toxicologically relevant chemicals, and producing the fewest false positive toxicological artifacts.

Budget: $100,000

Reducing Formaldehyde Emissions from Home Central Heating and Air Conditioning Filters

This project will explore the benefits of use of formaldehyde-free particle filters in residential heating and cooling systems. The study will expand on preliminary data showing that fiberglass particle filters contribute substantially to indoor formaldehyde concentrations. The project will collect data on how much fiberglass particle filters contribute to indoor formaldehyde concentrations across a range of humidity levels and

other conditions typical of California homes. This data will help inform decision-makers about whether synthetic and other formaldehyde-free filters are a part of the solution to reduce indoor formaldehyde exposures. The results of this study are expected to provide information that can be used to support revisions to the California's building code specifications for central heating and air conditioning filters that would reduce indoor formaldehyde exposure. Formaldehyde is a toxic air contaminant which poses a risk of cancer and other adverse health impacts.

Background: Based on recent research by Lawrence Berkeley National Laboratory (LBNL), fiberglass particle filters in central heating and air conditioning systems may be the next largest source of indoor formaldehyde levels after composite wood products. In limited laboratory and field studies, fiberglass particle filters produced indoor concentrations that exceeded OEHHA's non-cancer 8-hour and Chronic Reference Exposure Levels (RELs) for formaldehyde (both set at 9 $\mu g/m^3$). However, these preliminary results were based on just a few measurements under limited conditions. Further study is needed to quantify the contribution of fiberglass filters to indoor concentrations of formaldehyde in California homes and evaluate the benefits of synthetic and other formaldehyde-free filters. LBNL found that emissions of formaldehyde increased with increasing relative humidity (RH). At 50% relative humidity the use of fiberglass filters increased room formaldehyde levels by 18-24%, adding an average 4 $\mu g/m^3$ to room concentrations. This is significant because 98% of the California population lives in areas where the annual average RH level is 50% or higher. At 80% RH, room concentrations increased an average of 6 $\mu g/m^3$. For comparison, outdoor formaldehyde concentrations in California average 3.2 $\mu g/m^3$.

There is limited recent data for older California homes, but the median formaldehyde level found in a 2009 study of new California homes was 36 $\mu g/m^3$. ARB's composite wood regulation is expected to reduce new home concentrations by up to 40%, for an estimated median formaldehyde level of about 22 $\mu g/m^3$ in future new homes. Aside from composite wood products there are many other indoor sources of formaldehyde, but none are suspected to individually contribute as much formaldehyde as the fiberglass filters. The LBNL study suggests that changing filter type could reduce indoor concentrations by about 4-5 $\mu g/m^3$ in future new homes, but further research is needed to confirm and quantify these results under a variety of conditions found in California homes.

Methods: The investigators will measure formaldehyde emissions from fiberglass filters, synthetic filters, and other formaldehyde-free filters in bench-scale laboratory tests. Experiments will be performed across a range of real world conditions observed in California homes, including different humidity levels, temperatures, and air exchange rates. The contributions of fiberglass filters and formaldehyde-free filters under similar conditions will be compared to quantify the exposure reduction that would likely be achieved by using synthetic filters and other formaldehyde-free filters.

Budget: $350,000

ATMOSPHERIC SCIENCE

Current Research

ARB research continues to improve the scientific foundation for California's efforts to meet air quality standards and reduce the health risk from air pollution. To support efforts to meet NAAQS, research has resulted in improvements to emissions inventories, chemical mechanisms in air quality models, and field studies to better understand the nature of the air pollution problems in the South Coast Air Basin and San Joaquin Valley.
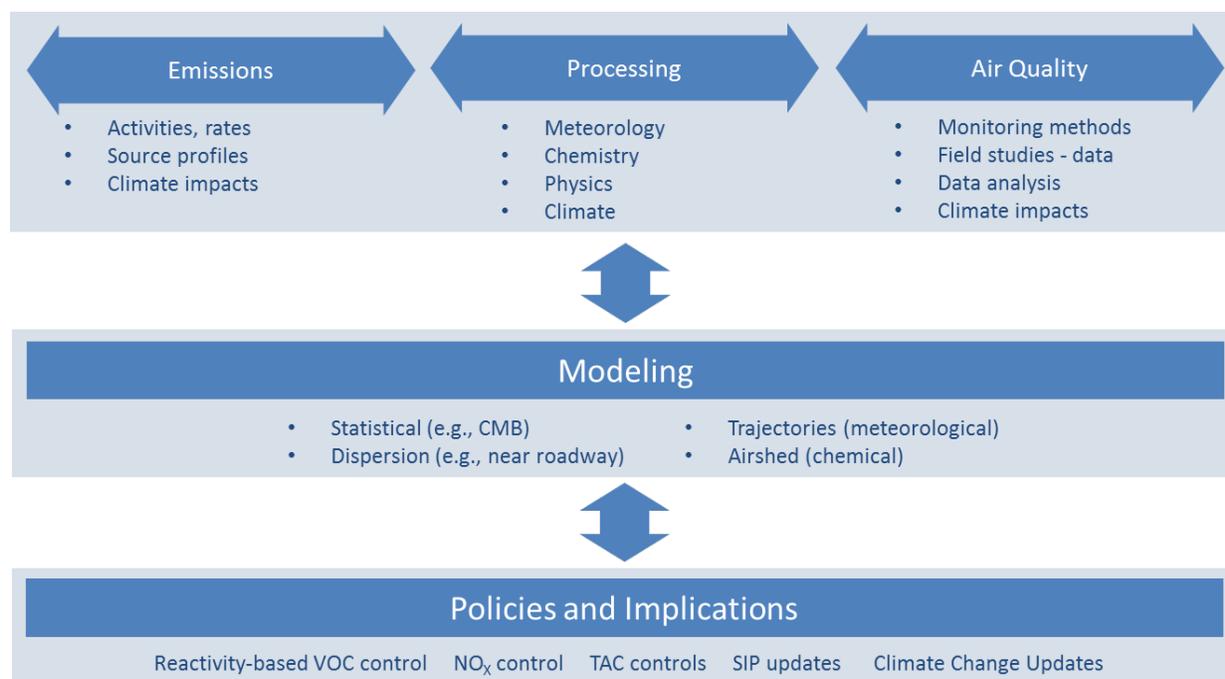
CalNex 2010 was an important field study with two monitoring supersites, multiple aircraft, a research vessel, and participation by over a hundred scientists. One supersite was in Pasadena and the other was in Bakersfield. The study was designed by ARB and National Oceanic and Atmospheric Administration staff to answer 12 policy-relevant science questions on air quality, climate, and their nexus throughout California. ARB's contribution to this research effort was leveraged by major contributions from NOAA and dozens of independently funded academic research groups who joined the study. NOAA is completing a synthesis report of policy relevant findings from the CalNex 2010 Field Study which will be presented to the Board in the spring of 2014.

Much of ARB's current air quality science research and research collaborations build on previous work. In addition to CalNex 2010, the Carbonaceous Aerosol and Radiative Effects Study (CARES) study funded by the Department of Energy, focused on the formation of carbonaceous aerosols in the Sacramento/foothills transport corridor. ARB is supporting additional analysis of PM2.5 components from the CARES study. The San Joaquin Valley was one of the deployment locations for NASA's DISCOVER-AQ in January/February of 2013, and some of the proposed research will take advantage of that effort.

While ARB continues to support improvements to the SAPRC chemical mechanism for gases, another project is developing the Statistical Oxidation Model (SOM) to provide multiple tools for modelers to address the complex problem of modeling secondary organic aerosol (SOA) formation. The sources, impacts of existing controls, precursors, and processes which form SOA are the focus of several research projects. Organic aerosols comprise a significant fraction of PM2.5 in California. Improving the knowledge of the portion that is SOA, as well as the sources and mechanisms of SOA formation, will improve PM2.5 modeling used in State Implementation Plans (SIP). Last year, ARB funded projects to address questions concerning organic compounds used in consumer products. These projects will answer questions about the actual impact of these compounds on ozone and SOA formation and the environmental fate of exempt "low-vapor-pressure" (LVP) VOCs.

ARB also sponsors two major series of scientific conferences biennially at the University of California at Davis. The first, the International Conference on Atmospheric Chemical Mechanisms (ACM), mainly focuses on gas-phase chemistry that leads to ozone

formation. The fourth ACM conference was held in December 2012. The second, International Aerosol Modeling Algorithms (IAMA) conference, is focused on the particulate matter formation mechanisms. The fourth IAMA conference will be held in December 2013.

Figure 4. Air quality science research spans the collection and analysis of air quality data, understanding emissions sources, and air quality and meteorological modeling. This scientific foundation supports development of effective strategies to reduce emissions and meet Clean Air Act requirements for State Implementation Plans (SIPs).

FY 2014-15 Research Focus

Decision-makers rely on results from air quality models to provide predictions of future air pollution levels for use in developing required air quality plans and emission reduction strategies. Air quality models are also used to explore the relative effectiveness of reducing specific air pollutants, and their precursors, to meet air quality standards. Improvements to air quality modeling systems involve input data, modeling algorithms, and key components of the models such as chemical mechanisms.

There are two projects proposed to improve aspects of ozone and particulate matter modeling for the San Joaquin Valley. The first project will collect airborne air quality and meteorological measurements to help understand how ozone and its precursors found aloft may impact ground level ozone concentrations. The aloft measurements are designed to capture the impact of nighttime chemistry and meteorology on the next day's ozone levels. The carryover of ozone from one day to the next impacts surface ozone levels, and the frequent temperature inversions, which form in the San Joaquin Valley, provide a mechanism for sequestering ozone and precursors aloft overnight. A

better characterization of the vertical profiles of pollutants in the atmosphere will enable improvements to ozone SIP modeling. The second project will support updates to the particulate matter modeling for the San Joaquin Valley needed to address the more stringent annual PM2.5 standard adopted by the U.S. EPA in 2012. This project will provide analyses of data collected during the winter 2013 DISCOVER-AQ study by NASA. This study captured two multi-day PM2.5 episodes in the San Joaquin Valley, and the data collected on the aircraft provides insights into conditions aloft which are key to PM2.5 formation over a period of days. Elevated concentrations during the winter are a key driver of the annual average. These measurements aloft will help update ARB's conceptual model of PM2.5 formation in the San Joaquin Valley.

Proposed Projects

- Characterization of the Impacts of Conditions Aloft on Surface Air Quality to Improve SIP Modeling
- Characterization of PM2.5 Episodes in the San Joaquin Valley Based on Data Collected During the NASA DISCOVER-AQ Study in the Winter of 2013

Characterization of the Impacts of Conditions Aloft on Surface Air Quality to Improve SIP Modeling

This project will collect measurements to characterize atmospheric conditions aloft to improve ARB's modeling of ozone concentrations in the San Joaquin Valley. The extent to which ozone and its precursors aloft (above what the traditional surface monitoring network samples) mix down after sunrise and kick-start ozone formation on days with high concentrations is currently unclear. This research project is designed to improve the accuracy of the modeled structure, mixing, and composition of the atmosphere by making air quality and meteorological measurements aloft on days anticipated to have high ozone concentrations at ground-level sites in the San Joaquin Valley. These measurements of conditions aloft will help improve the ozone modeling for the SIP.

Background: The San Joaquin Valley is classified as an extreme ozone nonattainment area for the 8-hour ozone NAAQS. All sources of ozone contributing to high ground level ozone concentrations must be reflected in air quality models in order to characterize atmospheric processes appropriately. Several of these contributing sources are associated with conditions in the atmosphere occurring above the area characterized by the routine ground level monitoring network. While past field studies have included some measurements of conditions aloft in the San Joaquin Valley, most of these older measurements no longer represent current conditions, or were not made when ozone concentrations were representative of ozone values which need to be used in developing SIPs. Additional research is needed to better characterize the role that ozone aloft plays in causing exceedances of the NAAQS. Because ozone aloft can persist many days with minimal titration or deposition, a reservoir of pollutants aloft can mix down in the morning and kick-start the generation of high ozone concentrations at ground-level. Knowledge of the vertical structure, mixing, and composition of the atmosphere is important for understanding and accurately modeling the causes of high concentrations of ozone in the San Joaquin Valley.

Methods: Detailed air quality and meteorological measurements will be made in the southern San Joaquin Valley during the development of at least two episodes with high ozone concentrations. This project would collect ozone and meteorological data aloft on a number of summer days forecast to exceed the ozone standard. The measurements will be used to improve the chemistry and advection/diffusion modules in air quality models that represent the atmospheric processes occurring above where the routine monitoring network can sample. These results will be used to improve ARB's ozone SIP modeling.

Budget: $300,000

Characterization of PM2.5 Episodes in the San Joaquin Valley Based on Data Collected During the NASA DISCOVER-AQ Study in the Winter of 2013

This project will further understanding of the formation processes, sources, and composition of PM2.5 in the San Joaquin Valley (SJV), and be used to update ARB's modeling of PM2.5 in the region. This project will investigate the physical and chemical processes that led to high PM2.5 concentrations in the Fresno area during the DISCOVER-AQ field study in the winter of 2013. The DISCOVER-AQ study collected data from multiple flights during two PM2.5 episodes. Analysis of this data will enhance understanding of PM2.5 formation in the SJV, and will provide updated information for use in SIP modeling for the revised annual PM2.5 standard adopted by U.S EPA in 2012.

Background: PM2.5 particles are both emitted and formed through atmospheric reactions of precursor pollutants. Concentrations are highest in the SJV during the winter, when cool stable conditions and low wind speeds coupled with the Valley's topography limit dispersion of emissions and allow multi-day buildups of PM2.5 concentrations to occur. The NASA 2013 DISCOVERY-AQ study was designed to explore the ability of satellites to diagnose surface air quality by characterizing high PM2.5 concentrations and relating them to satellite observations. The measurement program for this study occurred in January/February 2013 and created an extensive set of surface and aloft (aircraft) ambient data that further enhance the utility of the satellite data. This research project will perform advanced analysis on the San Joaquin Valley DISCOVER-AQ data set (aircraft and ground-based measurements), investigating the spatial and temporal distributions of the PM2.5 and its precursors, and their evolution during at least two extended episodes with high PM2.5 concentrations.

Methods: The project will analyze and model two basic sets of data: 1) surface data collected at a site in Fresno, featuring highly time-resolved data from several state-of-the-science real-time instruments (including a high-resolution mass spectrometer (HR-AMS), a PILS-IC, two SMPSs, a cavity ring down spectrometer, and a single particle soot photometer) and 2) multiple data sets collected by NASA's two aircraft, which include multiple spirals over surface monitors. The data will be analyzed to better understand the factors creating the 3-D structure and spatial variability of high PM2.5 concentrations.

Budget: $200,000

MOBILE SOURCE EMISSIONS

Current Research

ARB's mobile source emissions research program supports California's effort to meet NAAQS, reduce health risk from toxic air contaminants, and meet greenhouse gas (GHG) reduction goals. Research on vehicles and fuels supports the development and implementation of regulations and incentive programs that reduce transportation related emissions. Off-road mobile engines are also a high priority. ARB research monitors the effectiveness of emission reduction strategies to ensure that the expected air quality and public health benefits are achieved.
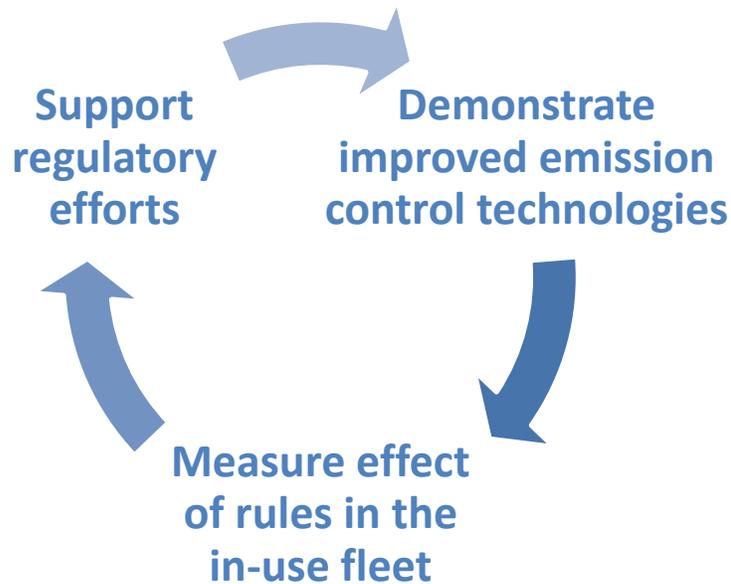
ARB research currently underway focuses on understanding the trends in the on-road emissions from light-duty vehicles, and tracking the results of regulations and programs to reduce diesel particulate matter (DPM) emissions by 85% by 2020. Research on diesel emissions is multipronged, and includes research on the effect of in-use rules for heavy-duty (HD) diesel vehicles (i.e. Drayage and Truck and Bus Rules), the durability, degradation, and failure rates of aftertreatment that reduces NO_x and DPM, and the real-world efficacy of NO_x controls. Research is also underway to explore the ability of current diesel control technology to achieve NO_x reductions beyond the current emission standards, which will be needed to meet increasingly stringent NAAQS over the next decade.

ARB's Truck and Bus Rule requires nearly all HD diesel vehicles operating in California to be equipped with diesel particulate filters by 2014, and the 2010 heavy-duty engine emissions standard for NO_x will result in the use of selective catalytic reduction (SCR) in most late model HD diesel vehicles. ARB has research projects in place to evaluate how well these aftertreatment controls perform in the real world over time. This research will also address the issue of cold starts and low-load operation in the HD diesel fleet since SCRs requires minimum temperatures of almost 200 degrees Celsius before any NO_x can be reduced. Results from this work will determine the overall effectiveness to selective catalytic reduction (SCR) in reducing NO_x from heavy-duty diesel vehicles.

Current research also includes the investigation of the long-term durability and degradation rates of HD diesel aftertreatment, specifically diesel particle filters and selective catalytic reduction (SCR). This will be accomplished using measurements of emissions from the in-use fleet in tunnels and at weigh-in-motion stations in California. Additional research is investigating the long-term trend in measurements of emissions using remote sensing from light duty vehicles in Los Angeles, which will provide an understanding of how well the emission controls continue to perform in vehicles subject to LEV I and LEV II.

In-house research also includes the deployment of a mobile measurement platform in collaboration with UCLA. The mobile monitoring platform measures key gaseous and particle species, including PM2.5, black carbon, carbon dioxide and NO_x, with high spatial and temporal resolution. This effort has shown that emissions of black carbon and NO_x from heavy-duty diesel trucks on a port truck dominated freeway were reduced by 50 percent or more from 2009 to 2011, with preliminary results suggesting decreases in pollution in nearby neighborhoods as well. In the coming years, this research tool will

be used to help evaluate the ability of soundwalls to reduce the impact of traffic emissions on nearby neighborhoods, and the effect of the built environment on air pollution exposures.

Figure 5. The vehicle emissions research process.

FY 2014-15 Focus

ARB's mobile source emissions research goals over the next 5 to 10 years reflect the need to continue to reduce emissions contributing to violations of NAAQS, to reduce health risk from toxic air contaminants, and to reduce greenhouse gases. For FY 2014-15, two projects are proposed to evaluate the adequacy of existing emission standards for NO_x and PM. Additional projects focused GHG reductions are discussed in the Climate Change section of this annual plan.

In the off-road sector, emissions standards have allowed smaller engines to be made and sold without the best available control technologies. The assumption has been that advanced aftertreatment would severely impact the cost of these smaller engines. This is especially relevant on a cost percentage basis as the technological cost component is a greater proportion of the total product cost for lower-power engines in comparison to average and higher power engines in the category. However, given the need for further emission reductions it is necessary to take another look at these engines to determine whether if aftertreatment is feasible and cost-effective. Another issue in the off-road sector is that engine manufacturers subject to most stringent new emissions standards, have been allowed to use emissions 'averaging' in demonstrating compliance. This regulatory flexibility results in fewer engines with the best available control, and may create certain vocations or geographical locations where engines emitting above standards are concentrated. There is a need to better understand the distribution of these engines in California, and the potential emission impacts on various locations Statewide.

Proposed Projects

- Evaluation of the Feasibility, Cost-effectiveness, and Necessity of Equipping Small Off Road Diesel Engines with Advanced PM and/or NO_x Aftertreatment
- Evaluation of The Impacts of Emissions Averaging and Flexibility Programs for All Tier 4 Final Off-Road Diesel Engines

Evaluation of the Feasibility, Cost-effectiveness, and Necessity of Equipping Small Off Road Diesel Engines with Advanced Diesel PM and/or NO_x Aftertreatment

This project will quantify the costs and performance of various emission control technologies, such as diesel particulate filters (DPF), selective catalyst reduction (SCR), and electronic fuel injection (EFI) for mobile off-road diesel engines with rated power less than 37 kilowatts (kW). These small (<37 kW) off-road diesel engines currently have less stringent standards than larger off-road engines. The project will also evaluate whether future regulatory measures to reduce emissions from this sector of the off-road industry are feasible and cost-effective. The results of this study will be used to determine whether or not small off-road engines should be subject to more stringent exhaust standards, identify reasonable levels of exhaust control based on costs, and support possible future amendments to the off-road diesel engine regulations in the 2016 timeframe.

Background: The majority of mobile diesel off road engines sold as new since 2011 are subject to regulations that require compliance with stringent diesel particulate matter (DPM) and NO_x exhaust standards based on the use of advanced aftertreatment technologies, such as DPF and SCR. However, off-road diesel engines less than 37 kW, such as loaders, tractors, pumps, compressors, generators, and refrigeration units produced by some manufacturers, are allowed to certify to less stringent emission standards. The reason for less stringent emission standards for small off-road equipment has been that advanced aftertreatment would severely impact the cost of these smaller engines. This is especially relevant on a cost percentage basis as the technological cost component is a greater proportion of the total product cost for lower-power engines in comparison to average and higher power engines in the category. Such findings were included in the U.S. EPA's Regulatory Impact Analysis (RIA) that was conducted in support of the 2004 federal rulemaking for adopting advanced aftertreatment standards (i.e., the current Tier 4 standards) for new off-road engines. At the time, anticipated emission control technologies were not in wide production so the RIA estimated the expected costs. However, some of the technologies anticipated in the RIA are now common today in both the off-road and on road diesel sectors. The "economies of scale" of today's market, as well as the availability of additional exhaust control strategies and techniques not evaluated originally in the RIA, warrants renewed consideration. Emission control technologies for small off-road equipment could assist in the reduction of statewide NO_x and DPM needed for California to attain its air quality goals. Small off-road equipment is estimated to contribute 27.6 tons of NO_x and 1.1 tons of DPM per day in 2020. These numbers represent 22 percent of the total off-road equipment NO_x emissions and 12 percent of total off-road equipment DPM emissions.

Methods: The proposed study will involve the emissions testing of several small off-road diesel engines representing a cross section of applications in the under-37 kW off-road diesel power category, including at least one engine commonly used in transport refrigeration unit applications. These engines will be modified to include various combinations of exhaust control technologies such as DPFs, SCR, EGR, EFI, and some will be modified to accommodate operation on alternate fuels, such as natural gas. Ideally, a complement of control engines will be evaluated concurrently with the modified engines. The investigation will also evaluate the overall emissions impact of this segment of the industry in order to assess the benefits of more stringent standards, and will seek to determine the representativeness of the existing test cycles for these smaller engines (e.g., discrete mode vs. ramped modal). Finally, the study will look at how increasing the cost of control might affect small diesel engine manufacturers, including potential market shifts toward gasoline-fueled engines if the relative cost of diesel-fueled engines increases.

Budget: $800,000

Evaluation of the Impacts of Emissions Averaging and Flexibility Programs for All Tier 4 Final Off-Road Diesel Engines

This study will examine the impact of the emissions averaging and flexibility provisions for compliance with Tier 4 final off-road emissions standards. The emissions impact of federal Averaging Banking, and Trading (ABT) program and the federal Transition Program for Equipment Manufacturers (TPEM) on the criteria pollutant emissions will be assessed for 2011 and later model year off-road diesel engines in California. The study will also identify possible options for ensuring that California does not receive more than its proportionate share of higher-emitting diesel engines under these programs, including federal action or ARB regulation.

Background: California is a participant in both the federally administered ABT and TPEM programs. These programs allow manufacturers to certify some engine families to previous less-stringent standards, as long as the manufacturer certifies enough engines below the more-stringent current standard to ensure its entire fleet average is at or below Tier 4 levels. However, because these programs are administered on a national level, it is likely that some states, or some regions within a state, may receive a disproportionate share of higher emitting engines. California's extreme ozone nonattainment areas need the full benefit of Tier 4 engines, making it important to understand the impact of the federal averaging and flexibility provisions.

Currently, there are no data to evaluate the distribution of ABT and TPEM higher emitting engines within California. Manufacturers are only required to report federal sales for engines certified under these programs. California-specific sales figures are needed. The Diesel Off-Road Online Reporting System (DOORS) includes Statewide engine totals for certain classes of off-road fleets and vehicles, and could be used to partially address program objectives at the Statewide level, but location specific use figures are needed.

Methods: The investigators will identify regions in California where the higher-emitting ABT and/or TPEM engines have been located, and determine whether California has

received more than a proportionate share of such engines. Additionally, the study will identify and quantify the number of sites with confined borders, such as landfills, construction sites, mining operations, etc., where higher emitting engines are prevalent, or at least make up a significant portion of the equipment fleet at the sites.

Budget: $300,000

CLIMATE CHANGE

TRANSPORTATION AND SUSTAINABLE COMMUNITIES

Current Research

ARB has several research projects underway to support California's efforts to reduce greenhouse gas emissions from the transportation system. ARB has initiated research that will quantify the electricity powered miles driven by advanced technology vehicles, analyze the charging behavior of electric vehicle drivers, explore how new car buyers' perceptions of zero-emission vehicles (ZEVs) influence their vehicle purchase decisions, develop methods for measurement of low levels of particulate matter emissions so that compliance can be reliably determined, and quantify the potential emission benefits of vehicle load reduction. Research in these areas will be coordinated with U.S. EPA and National Highway Traffic Safety Administration, and support the midterm review for the Advanced Clean Cars program.

Current research is also supporting the implementation of ARB's Low Carbon Fuel Standard (LCFS), which calls for a reduction of at least 10 percent in the carbon intensity of California's transportation fuels by 2020. The LCFS incentivizes the production and sale of low carbon-intensity transportation fuels by establishing a set of performance standards in the form of declining carbon-intensity levels that fuel producers and importers must meet each year for their fuel pools beginning in 2011. Two projects from last year's Research Plan are examining the potential to produce renewable natural gas and drop-in fuels at the commercial scale in California. Results from this research will maximize the market penetration of these alternative fuels and identify the technical, commercial, financial, marketplace, and regulatory barriers that need to be addressed. ARB also has a research project underway to model the air quality impacts of projected biomass and biogas utilization in the San Joaquin Valley and South Coast Air Basins.

Current sustainable communities research is aimed at supporting implementation of SB 375 as well as helping to pave the way to the 2050 climate goal. ARB research underway in this area covers a wide range of activities. Over the last few years, the Board has sponsored projects that address buildings energy use, consumer behavior, and reducing vehicle miles travelled and energy use in land use planning. Results from these projects will be translated into products that will assist local governments, planners, and other practioners to further reduce GHG emissions from the built environment.
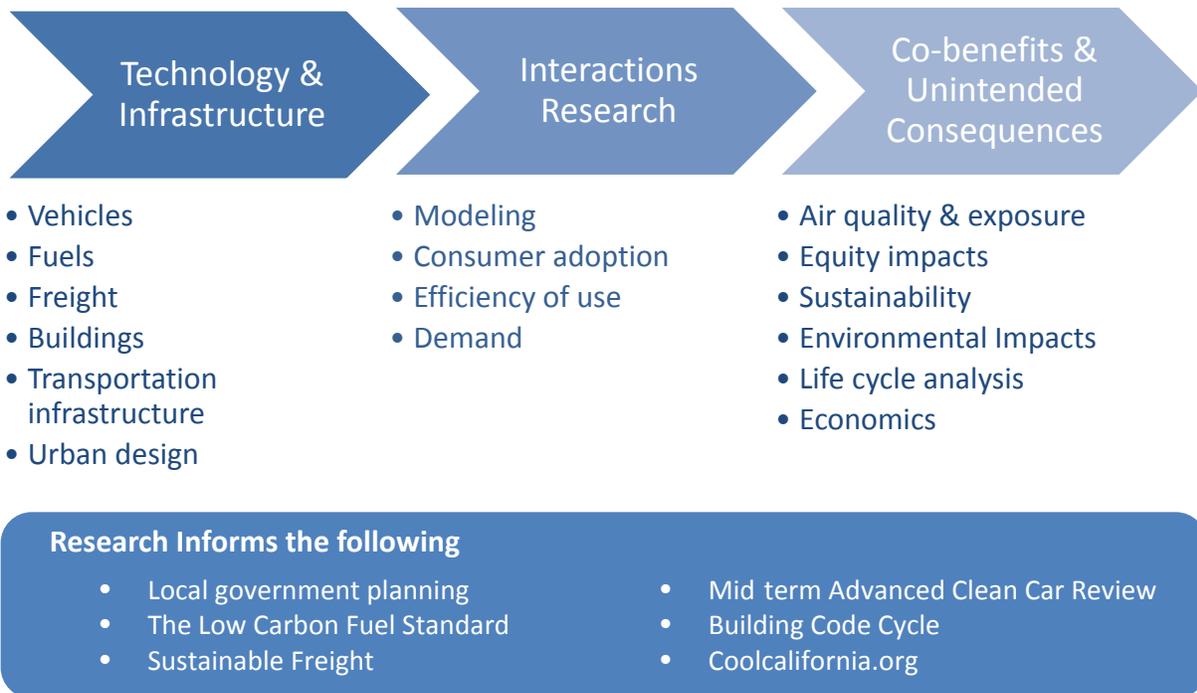
As California cities build more compact, transit-oriented development, it is important to understand the health co-benefits of this type of development and to identify solution for any potential unintended consequences. While the health research program focuses on strategies, such as high efficiency filtration in homes and vehicles, the sustainable community research is examining additional means to further reduce exposure to traffic pollution, particularly for communities already located near major roadways. Sound walls in combination with vegetation may offer potential for substantially reducing exposures of those living near busy freeways. However, research is needed to

establish the air pollution reduction effectiveness of adding different types of vegetation to sound walls in California. Information about the effectiveness and cost of a host of strategies can help guide State and local agencies seeking air pollution mitigation options to protect communities already living near freeways.

Additionally, a recently launched project will assess how more compact development may alter air pollution exposure of pedestrians and transit users near traffic-related pollution sources, and examine how urban designs and traffic management might mitigate such exposures. Community design features, including cool pavements, offer extensive climate and health benefits. However, information on their performance and impacts, as well as guidance and tools to aid decision makers in adopting these strategies are needed. To advance this, ARB funded the first cool pavement demonstration project in the State. In addition, ARB is proposing to evaluate the life-cycle impacts of conventional and cool California pavements and to create a decision support tool to help local and regional decision makers identify strategies to reduce the greenhouse gas, air quality, and heat island impacts of their pavement systems.

Several research projects are underway to support updates to the building standards and better quantify greenhouse gas reductions of green buildings. Current research is also looking to reduce GHGs from the building sector by investigating how Californians interact with building technology in the residential and commercial sector. Research topics include identifying the factors that play into energy consumption in residential and commercial buildings and how residential consumers respond to information about electricity consumption. Additional research is exploring how commercial building operators, managers, and occupants respond to advanced visualization of building energy use and how people respond to social incentives regarding electricity consumption.

In Figure 6 below, elements of ARB' research on short-lived greenhouse gases are illustrated, including research projects and in-house efforts.

Figure 6. Sustainable communities and transportation research program overview.

FY 2014-15 Focus

This year's focus is on addressing how to move people and goods more efficiently and with zero or near-zero emissions. Projects are proposed to support implementation of ARB's Advanced Clean Car Program, to evaluate potential strategies to further reduce greenhouse gas emissions from heavy duty trucks, and to support implementation of ARB's low carbon fuel standard.

Proposed Projects

- Emission Reduction Assessment of Trailers (Not Including 53-Foot or Longer Box-Type Trailers) Pulled by Heavy-Duty Tractors
- The Dynamics of Plug-in Electric Vehicles in the Secondary Market and their Implications for Vehicle Demand, Durability, and Emissions
- Potential to Build Current Natural Gas Infrastructure to Accommodate the Future Conversion to Near-Zero Technology
- "Well to Wheel" Pathways for Zero and Near Zero Technology in California's Heavy Duty Sector

Emission Reduction Assessment of Trailers (Not Including 53-Foot or Longer Box-Type Trailers) Pulled by Heavy-Duty Tractors

This project will provide information that would be used by ARB staff to assess the potential GHG emission benefits from improved trailer aerodynamics and reduced trailer

tire rolling resistance on heavy-duty tractors pulling trailers that are exempted from the Tractor-Trailer GHG regulation.

Background: ARB's Tractor-Trailer GHG regulation requires 53-foot and longer box-type trailers traveling in California to be equipped with aerodynamic technologies (e.g., side-skirts, rear trailer fairings, and undertray devices) and low-rolling resistance tires, resulting in improved fuel economy and reduced GHG emissions from the heavy-duty tractors that pull them. Additional work is needed to see if the aerodynamics of exempted trailers (e.g., 48-foot box-type trailers, "pup" trailers, flat beds, curtain sides, and tankers) that spend less time on the highways can be improved as well, and if those improvements would lead to significant GHG emission reductions. Freight Wing, Inc., a company recently acquired by Ridge Corporation, is a manufacturer of side skirt technologies. Freight Wing conducted wind tunnel testing on "pup" trailers at the Automotive Research Center and has published the test results showing a 5 to 10 percent GHG emission reduction in a November 11, 2012 report. Freight Wing has also conducted wind tunnel testing on flatbed trailers equipped with skirts, but the results have not yet been published.

Methods: The investigators will identify the exempted trailer-types to be studied and conduct wind tunnel testing of each trailer type to evaluate the impact on tractor fuel consumption due to the installation of trailer aerodynamic technologies. The testing would be done in accordance with SAE J1252. The investigators will also work with trailer fleet owners and data log the activity of a representative number of each trailer type.

Budget: $500,000

The Dynamics of Plug-in Electric Vehicles in the Secondary Market and their Implications for Vehicle Demand, Durability, and Emissions

This project will determine the longer term emissions benefits of plug-in electric vehicles (PEVs) based on the dynamics of these vehicles in the secondary market. While manufacturer compliance with the Zero Emission Vehicle (ZEV) program is based on new vehicles sales, the expected emissions benefits will require that these vehicles, including PEVs, remain in the fleet past the first owner. The results of this study will be useful to refine long term projections of emissions benefits from PEVs, and to inform future policy decisions, beginning in 2016, on the treatment of these vehicles by various ARB programs, such as incentives, durability requirements, or vehicle crediting.

Background: PEV sales over the past three years are approaching a total of 50,000 and many early consumers have been opting to lease rather than purchase these vehicles – either in response to competitive lease offers, uncertainty about current technology, and/or expectations for future developments – which will accelerate the development of a large secondary market of PEVs. This market will begin developing in late 2013, and initiating new research in these early stages will allow for comprehensive monitoring of its development process.

Methods: The investigators will examine vehicle and market data on PEVs procured through commercial sources and/or collected directly from consumers. The data may

be analyzed using statistics, econometrics, or other methods. The evaluation will look at contribution of factors such as battery life, energy prices, infrastructure availability, attributes and prices of new vehicle offerings, and economic conditions, on the demand and prices of used PEVs and on their usage. The analysis will also evaluate whether the secondary market is expanding access to advanced clean cars, such as PEVs, to a wider array of consumers. Additionally, the study will explore the variety of reasons that PEVs are entering the used market in order to gauge consumer acceptance of this class of technology.

Budget: $300,000

Potential to Build Current Natural Gas Infrastructure to Accommodate the Future Conversion to Near-Zero Transportation Technology

This project will investigate how the near-term development of natural gas infrastructure, in the heavy-duty transportation sector, can be implemented to include technology that can best facilitate the long-term conversion to near-zero technology. The United States is experiencing a period of plentiful supplies of domestic natural gas that is cheap, relative to diesel fuel. In response, several large medium and heavy-duty fleet operators have announced intentions to convert their freight vehicles to be powered by natural gas. This will result in significant investments in fueling infrastructure in the near term. The role of policies and/or incentives that encourage the use of infrastructure that can accommodate both natural gas and alternative fuels will be explored. This investigation will focus on infrastructure for medium and heavy-duty fleets with a scope that includes potential synergies with light duty infrastructure. ARB's 2011 LCFS Program Review Report indicates that a major barrier to expanded alternative fuel use includes the availability of appropriate fuel infrastructure. Results will provide strategies to maximize the current market penetration of fuel infrastructure that can accommodate alternative fuels in the long term, which will ease the transition to a zero or near-zero transportation sector in the future. If this research leads to the development of a seamless transition to low-carbon fuels, it will smooth implementation of the LCFS and benefit California consumers.

Background: The abundance of natural gas coupled with its low price and multiple applications across all sectors, means that it will continue to play an important role in the transportation and energy sectors in the near future. Natural gas is often touted as a 'bridge' to low carbon fuels in the heavy duty transportation sector, and the abundance of natural gas fueled medium and heavy-duty fleets are growing rapidly. Research is needed to determine what natural gas infrastructure would be economically and technologically ideal for both natural gas in the near-term, and alternative fuels in the long term. The original design of the LCFS provides time for the development of advanced, near-zero technologies. However, having infrastructure already in place to deliver alternative fuels to fleets, once more alternative fuels are already in place, will ease the future transition to zero or near-zero transportation technology. ARB's current research is addressing the development of the commercial-scale production of alternative fuels in California. This proposed project will complement ARB's on-going work by exploring optimum paths for developing infrastructure in the near-term that will accommodate these fuels once that are being produced at the commercial scale.

Methods: Alternative fuels that should be considered in this analysis include hydrogen, hythane, renewable diesel, renewable natural gas, dimethyl ether (DME) and any near-zero fuels that may be in demonstration phase. After a thorough literature review, researchers will compile costs and technological and environmental limitations for fuel infrastructure (pipelines, storage tanks, filling stations, delivery trucks, etc.) to accommodate both natural gas and alternative fuels, for all levels of medium and heavy-duty fleet operation (private small fleet operators to large commercial distribution). The researchers will then define the technological and/or economic barriers to the availability of multi-use infrastructure and develop potential strategies that could be implemented by State agencies to encourage the use of such infrastructure in the near-term.

Budget: $250,000

"Well to Wheel" Pathways for Zero and Near Zero Technology in California's Heavy Duty Sector

This project will analyze novel "well to wheel" pathways for the delivery of hydrogen and/or hythane fuel in the medium and heavy-duty sector and assess the criteria pollutant and greenhouse gas (GHG) emissions associated with each pathway. The project supports implementation of ARB's Low Carbon Fuel Standard (LCFS), which calls for a reduction of at least 10 percent in the carbon intensity of California's transportation fuels by 2020. This project should provide a better understanding of the scenarios to deliver hydrogen fuel to fleets in the medium and heavy-duty sector under different cost and technology constraints, as well as how that fits into the use of current natural gas transportation pathways. The project will also consider how these pathways could leverage the use of current light duty infrastructure and planned hydrogen infrastructure for light duty. Potential markets for hydrogen, outside of the vehicle-fuel sector, will also be identified to ensure a more rigorous and sustainable market.

Background: The LCFS includes the use of hydrogen fuel as a transportation fuel for both light-duty and heavy-duty vehicle applications. However, the GHG emissions for pathways that provide medium and heavy-duty trucks with fuel may vary significantly. For example, it is expected that the main source of hydrogen will come from the reformation of natural gas, the remainder from renewables, such as solar powered electrolysis, smart grid electrolysis, land fill gas reclamation, and other sources of renewable natural gas. The combination of delivery mechanisms will also impact emissions for a given pathway. A number of fuel pathways have already been evaluated and published by ARB staff on the LCFS website (http://www.arb.ca.gov/fuels/lcfs/lcfs.htm). However, there a number of methods to optimize the reduction of emissions from given pathways. For example, the placement of onsite and centralized hydrogen production facilities could be optimized to facilitate the use of hydrogen in medium and heavy-duty fuel-cell vehicles (FCV) and hybrid FCVs. These tradeoffs need to be qualified and evaluated for California's needs. This project will address which hydrogen fuel production and delivery pathways produce the least GHGs and criteria pollutants at the least cost.

Methods: In order to assess the most effective combinations of alternative fuels, fuel infrastructure, and vehicle powertrain technology to reduce GHG and criteria air

pollutant emissions, the researchers will begin by compiling information on the potential availability of hydrogen fuel in California and its potential to fuel short haul, regional and long haul medium and heavy-duty vehicles. The review must not duplicate analyses already conducted by ARB staff and posted on ARB's internet site. The review should also include a thorough search to identify potential hydrogen markets that can be served by hydrogen facilities concurrently and/or prior to the widespread introduction of hydrogen in the light and heavy duty sectors. Multiple pathways should be developed to address what medium and heavy-duty vehicle travel characteristics (e.g. short haul, regional, or long haul) are needed, as well as how these pathways fit into current natural gas transportation pathways and how they may need to be transformed. This integration with natural gas infrastructure could also allow for the assessment of pathways that produce hythane fuel. This task should include a geospatial analysis for the delivery pathways and an analysis of how these pathways could tie into the light duty sector hydrogen infrastructure planning. Emphasis should be placed on optimizing onsite and centralized hydrogen production facilities that cater to medium and heavy-duty vehicles and hybrid fuel-cell vehicles. The pathways will then be assessed for technological and economic feasibility, as well as criteria pollutant and GHG emissions.

Budget: $250,000

SHORT-LIVED CLIMATE POLLUTANTS AND NITROUS OXIDE
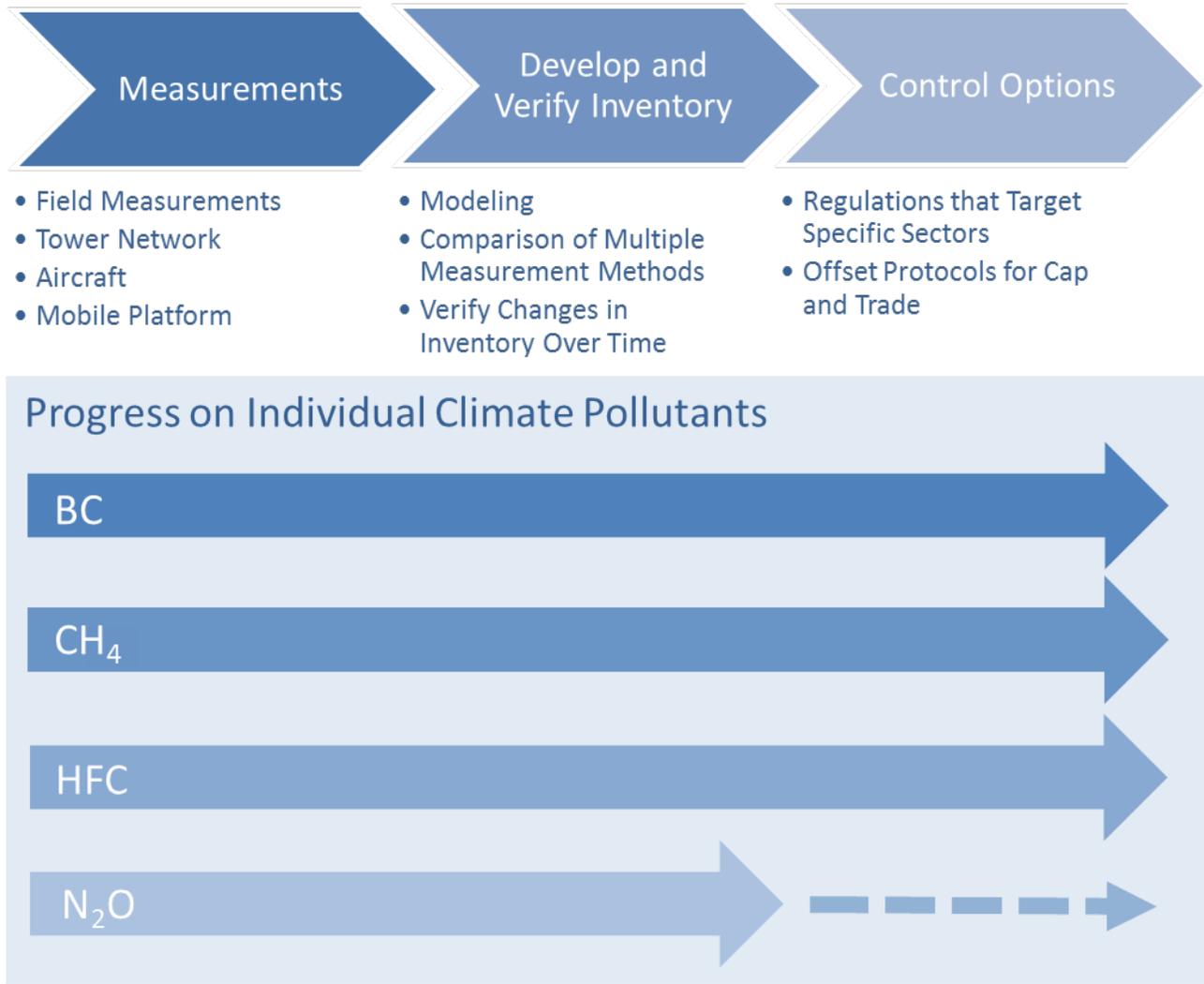
Current Research

Short-lived climate pollutants are climate forcing agents that have a relatively short lifetime in the atmosphere (days to a few decades). The short lived climate pollutants that ARB's research focuses on are black carbon (BC), methane (CH_4) and high global warming potential (HGWP) gases, such as hydrofluorocarbons (HFC). In contrast, nitrous oxide (N_2O) has an atmospheric lifetime of 120 years. However, all of these non-CO_2 climate pollutants have high global warming potentials. In an effort to attain California's climate change goals, ARB's research program has focused on emission measurements, inventory development, and the creation of control options for these climate pollutants.

Using California's existing GHG monitoring network, ARB is investigating the sources and trends of CH_4 emissions in Los Angeles by complementing a five-year GHG monitoring project funded by the National Institute of Standards and Technology. The initial analysis, utilizing the monitoring network data, suggests a potentially large underestimation of CH_4 and N_2O, but further work is necessary to confirm the results and then attempt to identify the source(s) of the poorly characterized emissions. ARB's mobile monitoring platform was successfully deployed at a landfill and a natural gas compression station, and further work is planned to use mobile GHG instruments to better characterize sources of CH_4 and N_2O and assess local impacts of implemented regulations. Some of the sources to be monitored may include oil and gas production sites, natural gas pipelines, wastewater treatment plants, landfills, and composting facilities.

ARB has focused its N_2O research program on nitrogen fertilizer use in California cropping systems, including developing mitigation strategies. ARB, the California Energy Commission, and the California Department of Food and Agriculture are currently conducting field experiments in a number of crop production systems, characterizing effects of different nitrogen management practices on N_2O emissions, especially those with mitigation potential. Efforts are also underway to develop and validate a geochemical model called DeNitrification-DeComposition (DNDC), which is widely used for simulating GHG emissions from agricultural ecosystems. The modeling project is expected to provide ARB with California-specific emission assessment tools that can be used to evaluate dynamics of spatial and temporal GHG emissions from California agricultural lands under various soil, weather, and crop management conditions.

Current research on HGWP gases is addressing emissions from landfilled insulating foam. Previous estimates have been theoretical and uncertain, as no studies have measured landfilled foam emissions in actual landfill settings. The results will be used to better quantify GHG emissions from the insulating foam sector, to better inform waste foam management policy, and to update landfilled foam emission factors used in the ozone depleting substances destruction offset protocol for more accurate estimates of potential offsets from waste foam destruction.

In Figure 7 below, elements of ARB' research on short-lived greenhouse gases are illustrated, including research projects and in-house efforts.

Figure 7. Research on short lived climate pollutants and N_2O. For specific gases, a solid arrow indicates a significant amount of research or the full implementation of some control options. However, there is ongoing research at all levels and for all gases. The dashed arrow for N_2O indicates that research on control measures has begun, but no offset protocols or regulations have been implemented.

FY 2014-15 Focus

Two research projects are proposed for short lived climate pollutants and N_2O. The first will characterize the contribution of brown carbon to climate forcing and air quality in California. The second project will develop a modeling tool to quantify the emission reduction potentials from various mitigation strategies that have been identified through previous ARB research.

Proposed Projects

- Characterizing the Air Quality and Climate Impacts of Brown Carbon
- Improving DNDC Modeling Capability to Quantify Mitigation Potential of Nitrous Oxide from California Agricultural Soils

Characterizing the Air Quality and Climate Impacts of Brown Carbon

This project will identify and characterize the contribution of brown carbon to air quality and climate forcing in California. Although brown carbon (BrC) is pervasive in the atmosphere, neither its sources nor the extent to which it contributes to direct aerosol climate forcing are well understood. State-of-the-art real-time measurement techniques will be deployed to determine the chemical composition and optical properties of brown carbon, their major source types, and to examine the climate response to brown carbon. The results will help us to determine the climate benefit of the ongoing mitigation of BrC emission sources in California, as well as providing immediate information that can be used to improve global climate models. Many short-lived climate pollutants (SLCP) are already regulated by ARB, either as part of the air quality and toxics program or under the Scoping Plan. In addition to pursuing existing strategies already under way, ARB will develop a SLCP strategy by 2016 that will include an inventory of sources and emissions, and a plan for developing necessary control measures.

Background: Carbonaceous particles (those that contain organic and black carbon) affect the radiative balance of the Earth by absorbing and scattering light and are abundant in the atmosphere. Organic carbon (OC) is normally assumed to be a pure scattering aerosol that leads to an overall cooling of the climate. However, recent experimental studies have demonstrated that a fraction of OC also absorbs sunlight with their absorption increasing dramatically towards shorter wavelengths. The absorbing part of OC is referred to as "brown carbon" because of its brown or yellow color. The sources of BrC and the extent to which it contributes to climate forcing are not well understood. Primary sources are thought to be mostly from biomass burning. However, secondary organic aerosols formed in the atmosphere may provide another source of brown carbon emissions. Furthermore, current climate models only treat brown carbon particles as a cooling agent. The BrC absorption could have a major impact on the direct climate forcing due to OC aerosols, just as the recent ARB project has shown for black carbon (BC) aerosols. The model results indicated that for the annual mean, the current top-of-atmosphere forcing of BC+OC varies from 0.2 Watts per square meter (W/m^2) over Northern California to as large as 1.9 W/m^2 over Southern California. Thus, models that neglect BrC severely overestimate the OC cooling effects.

A separation of the total aerosol absorption into different chemical species is essential, both for constraining the large uncertainties in current aerosol climate forcing estimates and for informing any emissions-based control policy. Direct aerosol climate forcing is understood now much better than 10 years ago. However, the tools to reduce uncertainties are still needed. Large uncertainties exist in current estimates of aerosol forcing because of incomplete knowledge concerning the distribution and the physical and chemical properties of aerosols as well as aerosol-cloud interactions. For example,

the aerosol indirect effect could vary by up to a factor of nine among climate models. Recent research activities are beginning to provide the needed inputs and constraints necessary to improve the accuracy of representation of aerosol effects in climate models. In addition they are allowing for a shift in estimates of aerosol radiative effect and climate forcing from largely model-based to an increasing level of measurement-model synthesis. Therefore, the light-adsorbing capacity of BrC should be incorporated into climate models so that its impact on net forcing can be assessed.

Methods: To characterize and differentiate sources of BrC from black carbon, advanced instrumentation will be deployed to collect chemical and optical properties of BrC sources and examine their contribution to OC in California. The instrumentation should include both high time resolution online non-filter-based instrumentation and detailed offline higher chemical resolution methods using appropriate low-artifact filters. Specifically, optical characterization should include both real-time measurements of suspended particles and additional filter measurements. Chemical characterization should include mass spectra of real-time submicron particles at high time resolution and offline measurements of functional group composition for both PM1 and PM2.5. Further, mass-based real-time measurements of BC at high time resolution should be included to characterize the non-OC absorption. Supporting measurements of size distributions should be included. This will include measurements at two sites in the San Joaquin Valley and South Coast Air Basins that investigate at least two types of BrC (e.g., residential burning versus urban secondary organic aerosols). The new observational capabilities together with dedicated aerosol modeling efforts will lead to a better understanding of the aerosol system, and to smaller uncertainties in estimates of BrC radiative effect and climate forcing.

Budget: $450,000

Improving DNDC Modeling Capability to Quantify Mitigation Potential of Nitrous Oxide from California Agricultural Soils

This project will develop and deliver a modeling tool that will allow for the quantification of the emission reduction potentials from various N_2O mitigation strategies that have been identified through previous ARB research. N_2O contributes about 15 million metric tonnes of CO_2 equivalents, or 3% of the California's GHG inventory. The majority of N_2O in California is produced by microbe-driven processes of nitrification and denitrification in the environment. Therefore, the surface fluxes of N_2O are highly variable, both spatially and temporally. Process-based models are useful in capturing this variability. The ability to quantify N_2O emissions under a variety of management practices will help identify effective mitigation measures to reduce emissions.

Background: Previous studies have delivered to ARB a validated California-specific modeling tool based on DeNitrification-DeComposition (DNDC), incorporating largely business as usual management practices for baseline emission assessment. However, the model needs further development to address changes in management designed for GHG mitigation purpose, and to scale up the limited field studies to estimate emission reduction potential from California agricultural soils Statewide.

Methods: The project will consist of the following tasks: 1) collect new field data from mitigation studies of N_2O emissions that have not been targeted before in previous DNDC validation (for example, the on-going UC Davis mitigation study by ARB and the paired studies by USDA assessing mitigation potential of selected mitigation options such as the use of nitrification inhibitors, dripping irrigations, specific nitrogen fertilizer types and different application methods, etc.); 2) improve the flexibility and robustness of the DNDC model in deriving N_2O estimates through additional DNDC model development, calibration, and validation for the selected mitigation scenarios and statistical analyses of DNDC model structural uncertainty to ensure model estimates are conservative; and 3) scale up the field studies to estimate mitigation potential of N_2O at the State level.

Budget: $200,000

NEXT STEPS

The 14 research projects proposed in this plan address key knowledge gaps and will strengthen the scientific foundation of health, air pollution and climate control programs, help develop future clean air regulations and programs, and measure the effectiveness of ARB's programs. Following Board action on the plan, staff will proceed to work with researchers to develop these research projects into complete proposals to be reviewed by ARB's Research Screening Committee and then brought to the Board for final funding approval. Results are anticipated in three to five years.