Annual Research Plan

Fiscal Year 2013-14

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California Environmental Protection Agency

Air Resources Board

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INTRODUCTION

For more than 40 years, the Air Resources Board (ARB or Board) and key public and private partners have collaborated to make California a center for pioneering air pollution research. 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 achieve three ambitious goals: 1) attain air quality standards, 2) reduce health risk from toxic air pollutants, and 3) meet greenhouse gas reduction targets.

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's air pollution control programs must address multiple pollutants, a series of federal deadlines, and greenhouse gas reduction goals in 2020 and beyond as shown in Figure 1. The projects included in this research plan will increase understanding of the health impacts of air pollution and California's progress on air quality, answer near-term questions important for program implementation, and explore benefits of longer-term strategies. This plan is organized around three overarching research themes: scientific foundation, clean air strategies, and program effectiveness:

Scientific Foundation – The core of ARB's research program is to understand the causes and impacts of, and identify potential solutions to, California's air pollution problems.

Clean Air Strategies – Addressing mobile sources, fuels, air pollution exposure mitigation, and sustainable communities, research in this area supports the development of new and innovative pollution-reduction strategies to ensure that ARB regulations and programs are based on the most up-to-date science.

Program Effectiveness – As new rules and programs phase in, ARB is actively pursuing evaluation efforts to verify that its regulations are effectively meeting their targets and protecting public health.

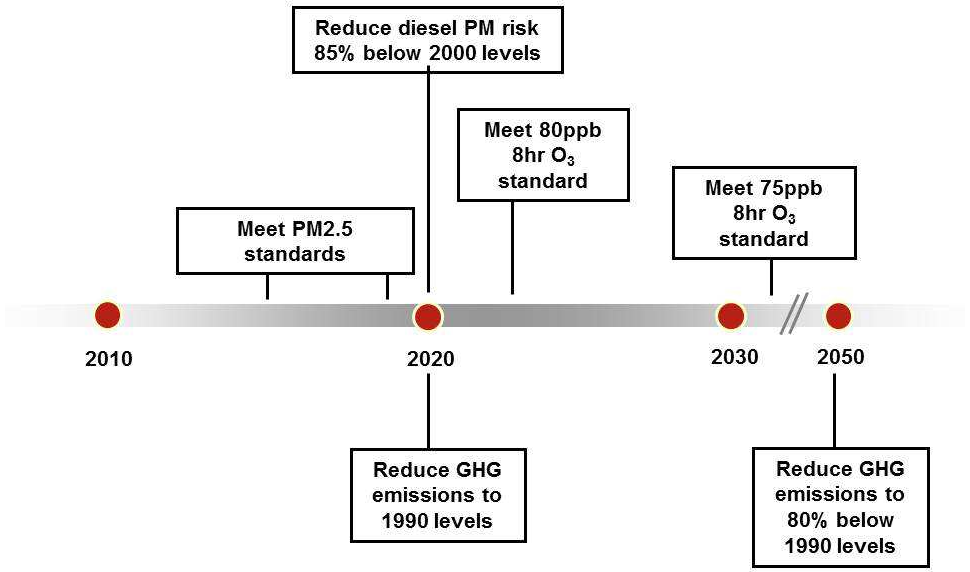

Figure 1. California's key air quality and climate change milestones through 2050.

The Fiscal Year 2013-2014 Research Plan includes nine research concepts, requiring approximately $4.3 million in funding. As shown in Figure 2, funding is allocated to research related to clean air strategies (49%), scientific foundation (41%), and program effectiveness (9%).

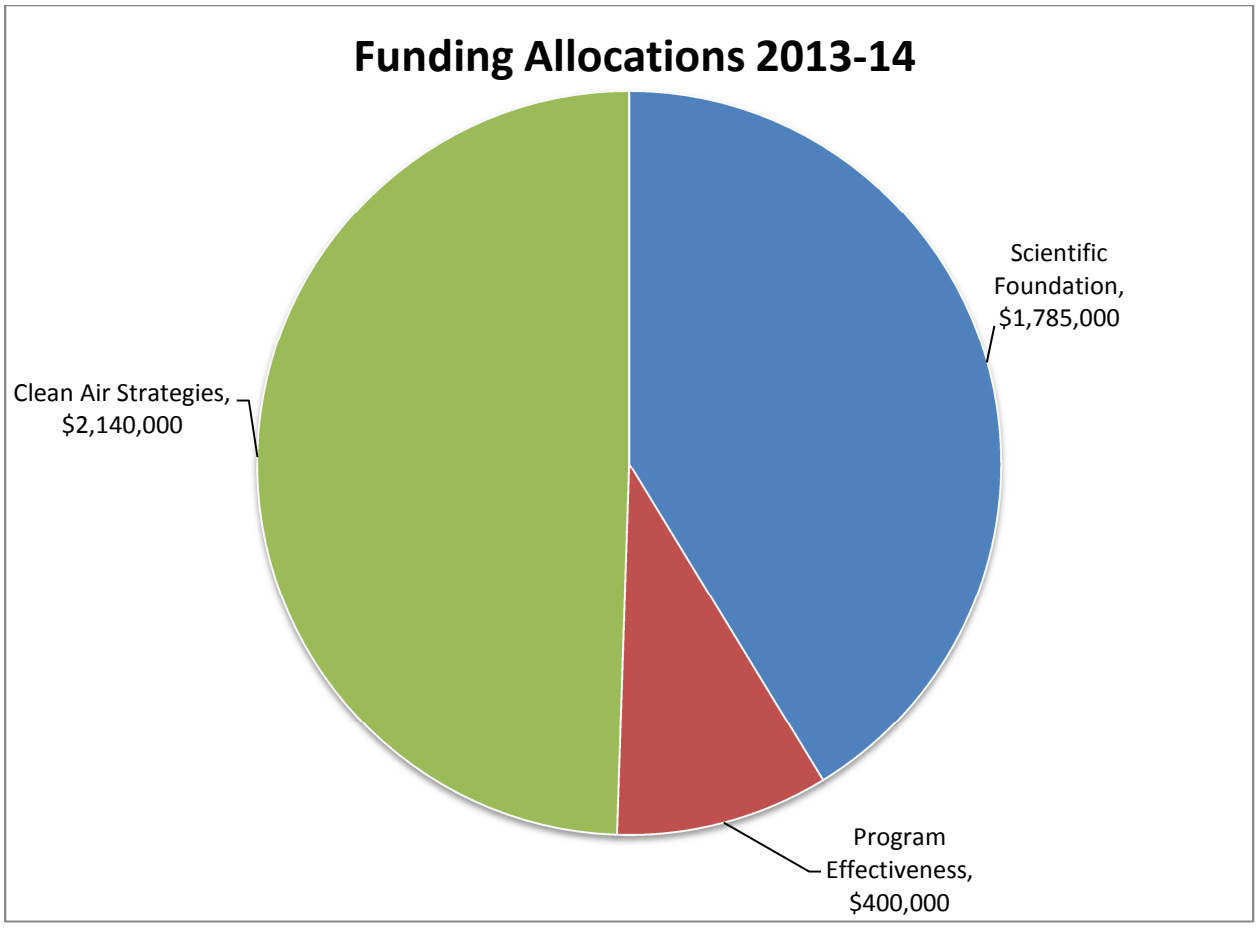

Figure 2. Proposed ARB research funding allocation for fiscal year 2013-2014.

PLANNING PROCESS

This research plan is designed to address the Board's highest priority program needs. ARB staff streamlined the 2013-2014 research plan development process in order to achieve three goals: 1) focus on ARB's highest priority program needs; 2) solicit more program relevant research proposals; and 3) utilize the entire three-year life of state funds allocated for research. ARB's research planning staff collected input from across ARB's Divisions to identify and prioritize research to support the agency's most pressing program needs, such as future updates to the State Implementation Plans, and implementation of the Scoping Plan, Advanced Clean Cars, Low Carbon Fuel Standard, and Sustainable Communities programs. Staff then released a solicitation for draft proposals which targeted the University of California and California State University systems. Draft proposals were evaluated by technical review teams that included

partners from federal and other state agencies as well as air districts. In parallel, ARB staff is soliciting the general public for research ideas, and will evaluate the submissions for possible inclusion in upcoming research plans.

Pending approval by the Board, the research projects described in this plan are ready to be quickly formalized into complete proposals to be reviewed by ARB's Research Screening Committee and then returned to the Board for final funding approval.

Coordination, Leveraging, and Collaboration

ARB works with air districts and other California and federal agencies to ensure that its research portfolio is non-duplicative of already funded work, leverages the State's available research funding, and produces results that have the greatest program benefits. ARB also continues to seek collaboration and co-funding opportunities and other ways to leverage limited research dollars. This coordination 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]).

Throughout the process of development of the research topics included in this plan, ARB staff has coordinated and will continue to coordinate with numerous other agencies and partners, including federal agencies spanning the U.S. Environmental Protection Agency (U.S. EPA), the Department of Energy, the Department of Transportation, National Highway Traffic Safety Administration, National Institute of Environmental Health Sciences, and 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), Office of Environmental Health Hazard Assessment, Housing and Community Development, and the Strategic Growth Council, as well as the local air districts and non-governmental organizations such as the Health Effects Institute (HEI) and the Coordinating Research Council.

Recent Research Highlights

Over the past 40 years, ARB has carried out scientific research in areas as diverse as the health effects of air pollution on vulnerable populations, the role of atmospheric chemistry in regional air pollution, and the impact of greenhouse gas emissions on climate change. Although ARB's research budget is modest compared to other funding organizations, the program has a long history of providing results that have influenced regulatory development at the state, national, and international levels. Below are a few recent highlights from ARB's research program.

Scientific Foundation

ARB's health effects research has helped form the scientific basis for development of state and national ambient air quality standards. Several ARB-funded research studies have recently added to the body of evidence on the impacts of fine particulate matter

(PM2.5) and ozone exposure on public health. For the first time, exposure to PM2.5 has been associated with the incidence of new cases of stroke in California women. In another California study, PM2.5 exposure has been found to increase the premature death risk from cardiovascular disease by 15 percent per 10 micrograms per cubic meter. ARB-funded research also showed that inhalation of PM2.5 can accelerate the formation of atherosclerotic plaques in mice, which can result in an increased risk of heart attacks and stroke. A study conducted in the San Joaquin Valley (co-sponsored by ARB and the Electric Power Research Institute) showed that while particles from different sources had differential effects depending on toxicological endpoint, all sources produced some level of toxicity. A controlled ozone exposure study found an effect on heart rate variability from high ozone levels alone, suggesting that short-term exposures to ozone can have acute cardiovascular effects.

Other ARB-funded research studies demonstrate the need to continue reducing Californians' exposure to air pollution, especially among vulnerable populations. An analysis of data from the California Health Interview Survey found relationships between asthma symptoms and air pollution exposures. Racial/ethnic minority and low income respondents had greater increases in adverse asthma outcomes for similar increases in nitrogen dioxide (NO_2) and PM10 exposures. Several studies measured elevated air pollutant levels in homes, daycare centers, and vehicles, underscoring the need to improve air quality indoors and in other enclosed environments. These research findings led ARB to put three research projects into place in 2011 to investigate the effectiveness of high-efficiency filtration in reducing pollution exposures in homes of asthmatic children, as well as in school buses and cars. Results from these research projects are expected within the next three years.

Over 60 papers have appeared recently presenting results from two major field studies in California. In May, June, and July 2010, ARB and the National Oceanic and Atmospheric Administration (NOAA) funded the California Research at the Nexus of Air Quality and Climate Changes (CalNex) field study. The study heavily leveraged ARB funds with large contributions from NOAA and a number of academic institutions. The objective of CalNex was to address scientific questions which impact both air quality and climate change. In June and July of 2010 the Department of Energy Carbonaceous Aerosols and Radiative Effects (CARES) study collected intensive measurements in the Sacramento and foothills area.

Major findings to date include top-down assessments of state and federal emissions inventories for ozone precursors, aerosol precursors, and greenhouse gases; the quantification of long-term trends in ozone precursor emissions and an improved understanding of the weekend effect in ozone in Los Angeles. The field studies brought instrumented aircraft, a research ship, and balloon-borne ozonesondes to the state, and provided a better understanding of the influence of stratospheric intrusions and long-range transport on surface ozone in California, and documented the benefits of California's low sulfur fuel usage by ocean going vessels. Super ground sites collected sophisticated measurements in Pasadena and Bakersfield, focusing on elucidating aerosol composition and formation processes.

ARB's research continues to improve our understanding of species important to climate forcing such as black carbon (BC) and nitrous oxide. One study found that the trend of

decreasing BC concentrations has occurred largely due to regulations and incentive programs to reduce diesel particulate pollution, and discovered the large effect of brown carbon (a form of organic carbon aerosols) on radiative forcing. In addition, ARB funded a project measuring nitrous oxide fluxes in five California cropping systems, which derived crop-specific emission factors of nitrous oxide under current management practices.

Clean Air Strategies

ARB's research continues to support the development and implementation of strategies to reduce air pollution and greenhouse gas emissions. Research topics span mobile sources, fuels, air pollution exposure mitigation, and sustainable communities. Past efforts have focused on a wide range of topics, but research aimed at improving emission control technologies for compressed natural gas-fueled buses and reducing emissions of hydrofluorocarbons and other high global warming potential greenhouse gases are highlighted below.

A collaboration among ARB, several universities, the South Coast Air Quality Management District and the Los Angeles Metropolitan Transportation Authority measured tailpipe emissions from diesel- and compressed natural gas-fueled transit buses with different types of aftertreatment under a range of operating conditions. While both fuel types met applicable emission standards for PM2.5 and nitrogen oxides (NO_X), results for toxic emissions varied greatly. These findings resulted in the installation of oxidation catalysts on all compressed natural gas-fueled buses to prevent high formaldehyde emissions, and the adoption of NO_2 limits for the heavy-duty diesel retrofit program to prevent enhancement of ozone and PM2.5 formation. This collaboration between ARB and university scientists continues with a systematic effort to measure the toxicology of particle emissions from new and emerging technologies and fuels for both light- and heavy-duty vehicles.

ARB-funded research on hydrofluorocarbons and other high-global warming potential greenhouse gases (up to 10,000 times as potent as carbon dioxide [CO_2]) demonstrated that emissions of these gases are growing rapidly and are produced from a variety of sources. Several research projects highlighted the importance and relative cost-effectiveness of reducing these emissions and led directly to adoption of ARB rules to reduce hydrofluorocarbons from commercial refrigeration, motor vehicle air conditioning systems, and other sources. These rules are expected to reduce annual statewide greenhouse gas emissions by 10 million metric tons of carbon dioxide equivalents in 2020 at relatively low cost and, in many cases, cost savings to industry. Finally, based on the results of this research effort, ARB adopted a protocol to provide incentives to recover and destroy a subset of these potent greenhouse gases (those that are also ozone-depleting substances) as part of the cap-and-trade program. Ongoing projects are investigating California sources of other important non-CO_2 greenhouse gases, such as methane (CH_4) and nitrous oxide (N_2O), and identifying ways to cost-effectively mitigate and reduce these climate-altering pollutants.

Program Effectiveness

The results of ARB-funded research studies help demonstrate how the Board's policies are leading to significant air quality improvements. Between 2007 and 2010, ARB's

emissions monitoring program detected a 50 percent reduction in diesel-related pollutants in heavily impacted communities (including the neighborhoods adjacent to the Ports of Los Angeles and Long Beach), due largely to the benefits of regulatory and incentive programs focused on port-related activities. Analysis of four decades of volatile organic compound (VOC) data in Los Angeles found that ambient VOC and carbon monoxide (CO) decreased by a factor of approximately 50 over five decades. Analysis of data collected aboard a research vessel found that California's first-in-the-nation regulations for ocean-going vessels – requiring that they switch to low-sulfur fuels and slow their speed as they approach the state's coast – reduce emissions by 88 percent or more for virtually all air pollutants.

SCIENTIFIC FOUNDATION

Attainment of health-based national ambient air quality standards drives many of ARB's regulatory programs. ARB's research program lays the scientific foundation for determining the causes and health impacts of California's air pollution, focusing on ozone and fine particulate matter, the only pollutants that still exceed national ambient air quality standards. The scientific and technical knowledge gained through this research has supported California's comprehensive air pollution control programs, making possible the dramatic improvement in California's air quality. For example, Los Angeles has not had a Stage 1 smog alert (one-hour peak of 0.20 ppm or more) since 1998. In 1990, the eight-hour design value was 0.186 ppm and there were nearly 200 days exceeding the 0.075 national standard. By 2012, the eight-hour federal design value for all of South Coast dropped in 2012 to 0.106 parts per million (down from 0.107 parts per million in 2011), with a maximum of 81 exceedance days in the region. Ozone concentrations meet the standards in much of Los Angeles County and all of Orange County, where much of the population lives and works.

CURRENT RESEARCH

California's air quality has improved significantly over the last few decades, but ozone and particulate matter levels continue to exceed health-based air quality standards in both urban and downwind rural areas of California. The Board has long been a pioneer in funding studies of air pollution's health effects, and results from ARB's health research program, as well as from studies funded by the U.S. EPA, HEI, and the National Institutes of Health, are the scientific basis for national ambient air quality standards for particulate matter and ozone. ARB has several ongoing and recently completed contracts that further our understanding of how air pollution adversely affects health. These projects include both mechanistic studies using animal models and human panel studies that, when published, add to the body of scientific literature that the U.S. EPA considers in their review of the national ambient air quality standards.

Despite decades of research progress, improved understanding of the formation and transformation of air pollutants is needed as the types and levels of air pollutant and precursor emissions change over time. And as air quality standards are tightened and emissions from California sources decline, emerging topics such as the contributions of previously unrecognized pollutant precursors, long-range transport of pollution from Asia, and intrusion of stratospheric ozone will need to be better understood. ARB is collaborating with national and international agencies on a wide variety of atmospheric studies; for example, ARB recently partnered with NASA on the DISCOVER-AQ study to research key air quality questions, primarily in the San Joaquin Valley, and with NIST to investigate the sources and trends of CO_2 and CH_4 emissions in Los Angeles as part of the Megacities project.

RESEARCH NEEDS

Although it has been well documented that air pollution exposure leads to adverse health impacts, the biological mechanisms which cause these associations are only

beginning to be understood. Research is needed to improve understanding of the mechanistic pathways through which inhaled particulate matter and ozone exposure cause health effects (particularly cardiovascular effects), and to evaluate whether the effects of concurrent exposure to PM2.5 and ozone are additive or synergistic.

Research on volatile organic compound (VOC) emissions and reactivity has been an ongoing effort necessary to improve understanding of ozone formation and to develop effective control strategies. Low vapor pressure (LVP) VOCs are ingredients used in some consumer product formulations to meet VOC limits because the ARB consumer products regulations provide an exemption for LVP-VOCs. The LVP-VOC exemption was initially developed to exclude compounds that do not readily participate in ozone formation (i.e. resins, surfactants, and other non-volatile organic compounds) and typically represented a small fraction of the overall composition of a formulated product. However, some recent laboratory testing indicates that certain LVP-VOCs may be present in the gas phase under ambient conditions, so it is important to better understand the contribution of LVP-VOCs to ozone formation. Research is needed to advance our understanding of the emissions of LVP-VOCs, the partitioning of LVP-VOCs between gas and particle phases in the atmosphere, and their environmental fate, to better assess the impacts of LVP-VOCs on air quality.

PROPOSED PROJECTS

Three projects are proposed to ensure that ARB's scientific foundation research focuses on key research needs and links closely with ARB's mission. These projects will improve ARB's ability to protect public health by examining the health effects of multipollutant exposures and investigate the air quality impacts of low vapor pressure volatile organic compounds.

- A Possible Mechanistic Pathway for Cardiovascular Effects of Co-exposure to Ozone and PM2.5
- Effects of Multipollutant Synergies on the Cardiovascular Impacts of Air Pollution
- Air Quality Impacts of Low Vapor Pressure-Volatile Organic Compounds

A Possible Mechanistic Pathway for Cardiovascular Effects of Co-exposure to Ozone and PM2.5

Objective: The objective of this study is to examine a hypothesized mechanistic pathway for the cardiovascular effects of ozone and PM2.5, and to examine whether the effects of co-exposure to these pollutants are additive or synergistic in laboratory experiments.

Concept: To date, most studies of air pollution exposure have focused on single pollutants, in contrast to the complex, multi-pollutant mixture to which the population is regularly exposed. Epidemiologic studies have consistently shown that PM2.5-related health effects on the cardiovascular system are larger and more clinically significant than those on the respiratory system. Recent research suggests that ozone exposure may also lead to previously unrecognized cardiovascular effects, but little is known about potential biological mechanisms for PM2.5- or ozone-induced cardiovascular

effects, or whether or not there are interactions or synergies with concurrent exposure to both pollutants. This study will examine a hypothesized mechanistic pathway for PM2.5- and ozone-induced cardiovascular dysfunction in an animal model, specifically looking at how pulmonary, vascular, and neuronal actions converge to cause cardiovascular morbidity and mortality in normal and hypertensive rats. The researchers will monitor the rats' breathing patterns and heart rate variability during various exposure regimens to examine the influence of PM2.5 and ozone exposure on cardiac function, and after the experiment will take blood samples and perform other measurements to evaluate various health endpoints indicative of impacts on function of the animals' cardiovascular systems. The results of this study will improve understanding of the mechanisms and potential interactions between ozone- and PM2.5-induced effects on the cardiovascular system that are relevant and can inform setting health protective ambient air quality standards

Proposed Funding: $600,000

Effects of Multipollutant Synergies on the Cardiovascular Impacts of Air Pollution

Objective: This study will examine the cardiovascular influence of co-exposure to ozone and PM2.5 on progression of atherosclerosis in laboratory animals, with specific emphases on investigating additive or synergistic effects among ozone, PM2.5, and the organic fraction of PM2.5, and seasonal variations in ozone and PM2.5.

Concept: Humans are exposed to a complex mixture of ambient air pollutants, but little is known as to whether or not there are interactions or synergies that result from simultaneous exposure to multiple pollutants, particularly ozone and PM2.5. Many studies have reported a significant association between exposure to either PM2.5 or ozone and adverse cardiovascular effects, and since both ozone and PM2.5 cause inflammation and can induce oxidative stress, combined exposure may lead to additive or synergistic effects. Further research is needed to understand the effects of co-exposure to ozone and PM2.5 on atherosclerosis, and therefore to expand the body of knowledge on the real-world health effects of air pollution. For this project, researchers will concentrate real-world air particulate matter and expose mice to various concentrations of PM2.5 and ozone, each alone, and in combination. The mice will also be exposed to air samples containing ozone and PM2.5 in which the organic components of PM2.5 have been removed, in order to test the hypothesis that progression of atherosclerosis related to exposure to motor vehicle pollution sources is related to organic compounds that are present in the emissions. The researchers will examine various health endpoints related to atherosclerosis to determine the mice's acute and chronic cardiovascular response to these exposures. The results of this study will contribute to the development of health-protective air quality standards, and could help guide development of more efficient future emission control strategies and methodologies that reduce emissions of more than one pollutant simultaneously.

Proposed Funding: $585,000

Air Quality Impacts of Low Vapor Pressure-Volatile Organic Compounds

Objective: The objective of this project is to investigate the emissions of LVP-VOCs from consumer products and to better understand their impacts on air quality and compliance with federal ozone standards.

Concept: The rates of volatilization of LVP-VOCs in different formulations of consumer products and the fate of those LVP-VOCs are not well characterized. Moreover, the ambient concentrations of LVP-VOCs are affected by both the rate and extent of release from emission sources and may be affected by the rate of removal through a variety of competing processes including disposal down the drain, atmospheric reactions, and dry deposition. Further understanding of the partitioning of LVP-VOCs and their reaction products between gas and particle phases in the atmosphere will improve ozone air quality modeling used in State Implementation Plans. This research project will investigate the ambient rates of volatilization of LVP-VOCs used in various consumer products sold in California. The project will employ chamber studies on selected LVP-VOCs and products that contain them, and will compare the air quality impacts of both the pure LVP-VOCs and their use in formulated products. The researchers will investigate the environmental fate of the LVP- VOCs and examine the air quality impacts associated with disposal, including disposal down the drain (e.g., emissions at water treatment or solid waste facilities). The results of this research will provide necessary technical information for ARB to better assess impacts of LVP-VOCs on ozone formation and provide data to help assess the impact of the exemption for LVP-VOCs in the ARB consumer products regulations.

Proposed Funding: $600,000

CLEAN AIR STRATEGIES

Supporting the development of clean air strategies remains a cornerstone of ARB's research program. When AB 32 was enacted in 2006, ARB's research program expanded to include studies examining emission reduction opportunities ranging from high-global warming potential industrial gases to voluntary strategies based on climate-friendly behavior, and these research efforts have led directly to some of the regulations and programs now in place to meet the 2020 greenhouse gas emission target. With the enactment of the Sustainable Communities and Climate Protection Act of 2008 (Senate Bill 375 or SB 375), ARB's research program included new areas such as integrated land use, housing and transportation planning. Meeting long-term air quality and climate goals will require well-integrated control programs, a transition to zero and near-zero emission technologies, and careful study and mitigation of any unintended effects.

ARB continues to pursue integrated air quality and climate goals and is working to ensure that all Californians share in the benefits of these efforts. Research in this year's plan will encompass a broad range of climate and air quality strategies, spanning light-duty vehicles, fuels, air pollution exposure mitigation, and social equity impacts of SB 375. These projects seek to balance air quality, climate, and societal goals.

ADVANCED CLEAN CARS

Passenger travel is a major source of both criteria and toxic air pollutants and greenhouse gas emissions in California. To meet long-term air quality and climate goals, emissions from vehicles will need to be significantly reduced beyond what is expected from already adopted regulations. The Advanced Clean Cars program will provide substantial emission reductions from light-duty vehicles consistent with Clean Air Act deadlines and climate goals. In 2012, Governor Brown signed Executive Order B-16-2012, establishing goals to reduce transportation-related greenhouse gas emissions by improving Californians' access to electric vehicles and charging infrastructure. The Advanced Clean Cars program is a key part of ARB's effort to meet these goals.

Current Research

ARB has funded extensive research related to a variety of mobile source control strategies as have multiple local, state, and federal agencies. Research and development activities beginning in the 1990s led to the Low Emission Vehicle (LEV) I, II, and III (i.e., Advanced Clean Car) hydrocarbon, hydrocarbon reactivity, NO_X, particulate matter, and eventually greenhouse gas emission standards for cars. Previous and on-going research on light-duty vehicles, sponsored by ARB, U.S. EPA, NHTSA, and the U.S. Department of Energy (DOE), has examined the technical feasibility and/or cost-effectiveness of emissions reduction technologies or strategies, though largely at the vehicle (as opposed to fleet) level. Other state and federal research has also focused on developing a better understanding of consumer vehicle purchase decisions, as well as usage of these vehicles, in order to improve models of the current and future motor vehicle fleets' emissions and energy consumption.

Research Needs

Continued advancements in technology and subsequent vehicle offerings necessitate ongoing research to ensure that the expected emission benefits from existing and future regulatory programs are realized. ARB has committed to a midterm review of the Advanced Clean Cars program, coordinated with U.E. EPA and NHTSA. To support the midterm review and Executive Order B-16-2012, 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 NHTSA.

This year's research plan includes an additional project to support the midterm review. This project will comprehensively characterize the current ZEV market. Although the ZEV-owning population is currently relatively small, evaluating recent ZEV purchases will help us understand the future market.

Proposed Project

The proposed project will investigate the factors that influence sales of ZEVs in California (e.g., price, vehicle range, infrastructure, etc.) and will support implementation of ARB's Advanced Clean Cars program.

- Examining Factors that Influence ZEV Sales in California

Examining Factors that Influence ZEV Sales in California

Objective: Achieving the goals of the Advanced Clean Cars program and Executive Order B-16-2012 will require increasing consumer purchases of zero-emission vehicles. The objective of this research is to understand the emerging ZEV market in California.

Concept: Consumer response to future ZEV offerings and incentives will be important as the market continues to evolve and expand in number and diversity. While the California Energy Commission has conducted several studies in the past on consumer response to alternatively fueled vehicles and incentives, these have relied on stated preference responses to hypothetical future vehicles. Now that ZEVs are commercially available, some research from the EV Project and the California Center for Sustainable Energy (administrator of the State's Clean Vehicle Rebate Program) has been able to evaluate real-world consumer response. However, these studies have been limited in geographic scope, vehicle types, and/or sample size. ARB's existing research project on consumer valuation of ZEVs focuses on the general new car buyer's perception, not only owners of ZEVs. This project would complement these existing efforts by evaluating the ZEV market in detail from a more holistic perspective and provide a measure of the representativeness of survey and interview respondents to the overall

ZEV buying population. Researchers will merge monthly ZEV registration data with census tract data in order to correlate the factors that influence ZEV sales across California using econometric methods. Policy-driven factors such as purchase rebate levels and access to high-occupancy vehicle (HOV) lanes; market conditions, such as gasoline and electricity prices and the attributes and diversity of vehicle offerings; geographic factors, such as proximity and availability of electric chargers, local built environments, and neighbors purchasing similar vehicles, and demographic characteristics; and the attributes and diversity of vehicle offerings will all be considered. The results of this study will be used to describe the current ZEV market and to refine future estimates of ZEV market potential in California.

Proposed funding: $265,000

LOW CARBON FUEL STANDARD

In order to achieve California's climate and air quality goals, emissions from transportation will need to decline significantly in the coming decades. ARB's Low Carbon Fuel Standard (LCFS) 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.

Current Research

Certain industry studies have contended that the fuels necessary to comply with the LCFS standards in the 2015 timeframe will not be available when they are needed, but these studies are both pessimistic with respect to availability, and also focus on the assertion that the LCFS will have large cost impacts on consumers. There are already examples of low carbon intensity fuels coming into the market, for example, the landfill gas-to-liquefied natural gas (LNG) facility at the Altamont landfill produces enough LNG to power a portion of Waste Management's fleet. Additional studies have indicated that biofuels will be needed to achieve long-term energy and climate goals in the transportation sector, especially for aviation, shipping, heavy-duty and off-road vehicles that cannot be easily electrified. 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.

Research Needs

Although drop-in fuels are essential to meeting California's climate change and air pollution goals, the technology and infrastructure needed to commercially produce these fuels through economically viable pathways still requires significant research. Maximizing the market penetration of renewable natural gas requires research to identify the technical, commercial, financial, marketplace, and regulatory barriers that are specific to renewable natural gas production.

Proposed Projects

The two proposed projects address several key research issues related to low carbon fuels.

- The Future of Drop-In Fuels: Life Cycle, Costs and Environmental Impacts of Bio-Based Hydrocarbon Fuel Pathways
- Feasibility of Renewable Natural Gas as a Large Scale, Low-Carbon Substitute

The Future of Drop-In Fuels: Life Cycle, Costs, and Environmental Impacts of Bio-Based Hydrocarbon Fuel Pathways

Objective: This project will investigate the technology, feasibility, costs, barriers, and environmental impacts associated with producing drop-in fuels on a commercial scale for use in California.

Concept: ARB's LCFS is a cornerstone of California's effort to meet AB 32 goals, and requires the development of lower carbon fuels and the adoption of more efficient, advanced technology vehicles. The original design of the LCFS provides time for the development of these technologies, but in order to achieve commercial production, the technologies need to be encouraged now. Although there are several types of renewable fuels, drop-in fuels (i.e., fuels that, once produced, are nearly identical to fossil-derived gasoline and diesel) would require the least modification to the existing infrastructure and vehicle fleet. If a low carbon intensity drop-in fuel were developed, it would aid in compliance without adding costs associated with fleet turnover and additional infrastructure, but the fuel needs to be available in sufficient quantities and at competitive prices. A recent ARB staff report examined several technology transformation scenarios needed to meet California's 2050 goals for the reduction of both greenhouse gas and criteria pollutant emissions, and the scenarios in this report include an assumption that all liquid fuels would be derived from renewable feedstocks by 2050, preferably in the form of drop-in fuels. Since drop-in fuels are in a research and development phase, with pilot- and demonstration-scale plants under construction, further research on the technology and infrastructure is needed. The researchers will gather existing information and analyze the technology and feasibility, and the life cycle costs and environmental impacts, at both demonstration and commercial scales. The researchers will perform a geospatial analysis to estimate where facilities could potentially be located in order to maximize production while minimizing environmental impacts. Research needs and barriers to the success of these technologies will be identified, as well as strategies to overcome these barriers. Strategies to monitor and track progress of these technologies as well as supplies and costs will also be developed. The project results will provide data that will influence LCFS policy in California or other jurisdictions worldwide that are developing their own LCFS-like programs. If this research leads to the development of lower carbon fuels, it will be to the benefit of regulated parties under the LCFS and to California consumers. In the longer term, the data will inform many other initiatives of ARB that might support the need for drop-in fuels.

Proposed Funding: $400,000

Feasibility of Renewable Natural Gas as a Large Scale, Low-Carbon Substitute

Objective: This project will determine the technological and commercial feasibility of producing large quantities of renewable natural gas fuels for use in California.

Concept: Alternative fuels that have low greenhouse gas and criteria pollutant emissions, such as renewable natural gas, are essential for California to meet its climate change and air quality goals. ARB's LCFS is designed to reduce California's dependence on petroleum, including the use of renewable natural gas as a transportation fuel for both light-duty and heavy-duty vehicle applications. The feasibility of widespread, large-scale production of renewable natural gas, especially for transportation use, remains uncertain, with a number of research needs that will assist with appropriate policymaking. The LCFS regulation already incorporates a number of pathways for renewable natural gas derived from landfill gas and dairy digesters, and there's a pending pathway for renewable natural gas derived from high solids anaerobic digestion of organic wastes. All these renewable natural gas pathways have substantially lower carbon intensity than both conventional diesel and fossil natural gas. To maximize the market penetration of renewable natural gas, it is essential that technical, commercial, financial, marketplace, and regulatory barriers that are specific to renewable natural gas production be identified. ARB's 2011 LCFS Program Review Report indicates that barriers to expanded natural gas usage include infrastructure, conversion of existing vehicles to use natural gas, the higher cost and more limited selection of original equipment manufacturer vehicles, and vehicle conversion. This project will examine renewable natural gas production and distribution, particularly for transportation fuel use in California. Researchers will develop a map of current and potential sources for renewable natural gas production, both in California and elsewhere in the U.S., identifying, analyzing, and comparing the technology and production methods involved, feasibility, costs, environmental impacts, advantages/disadvantages, volumetric capacities, and distribution methods to bring the fuel into California for vehicular use. The analysis should consider optimizing facility locations in order to maximize production of renewable natural gas while minimizing potential environmental impacts, and should provide a preliminary estimate of the life cycle greenhouse emissions as well as localized emissions of criteria and toxic air pollutants, and other potential environmental and public health impacts that are of significant concern. Researchers should also identify barriers to the successful expansion of renewable natural gas production, and, where applicable, strategies to overcome these barriers, such as possible refinements to the LCFS regulation itself, and should identify additional areas of research. Results will provide essential data that will inform future refinements to the State's LCFS program and other climate change and air quality initiatives.

Proposed Funding: $325,000

SUSTAINABLE COMMUNITIES

Strategies to promote sustainable communities seek to improve air quality and health, and reduce greenhouse gas emissions. Sustainable communities program goals

include safe, reliable, and affordable transportation choices, equitable and affordable energy- and location-efficient housing options, and improved access to quality employment, education, and other resources and services. ARB's air quality and climate goals strongly support the development of sustainable communities, and ARB continues to work to ensure that all Californians share in the benefits of these efforts.

In support of developing more sustainable communities, state law (SB 375) encourages California transportation and land use agencies to consider greenhouse gas impacts of their planning processes. Each of California's metropolitan planning organizations (MPOs) is required to develop a Sustainable Communities Strategy (SCS) that demonstrates how—through integrated land use, transportation, and housing planning—they will meet regional greenhouse gas reduction targets set by ARB. Planning for more compact growth with transit-rich neighborhoods is one of the strategies being pursued by regions as they work toward SB 375 goals, and shows promise as a means to reduce greenhouse gas emissions and achieve other health co-benefits. However, there remains concern that improving transit services and concentrating growth around transit services may have unintended social equity impacts. Introducing or improving transit services and increasing development investment in existing neighborhoods may increase the desirability of the area. As a result, rent and housing prices in the vicinity may increase, which may lead to displacement of current low-income residents—those who most need access to public transit. Research is needed to evaluate the potential impact of transit-oriented development on displacement, and to identify solutions.

Another issue associated with compact development in urban areas is the potential to increase air pollution exposure to traffic emissions. Exposure to traffic emissions has been associated with a variety of serious health impacts, and children appear to be particularly vulnerable. While ARB continues to adopt increasingly stringent regulations to reduce vehicle emissions, recently adopted regulations have compliance dates extending as far as 2025 for full implementation, and fleet turnover to zero or near-zero technologies will take 20 to 30 years. Unhealthful levels of air pollution near roadways remain a long-term problem. Approaches that reduce near-roadway traffic pollution exposure for communities currently living near freeways would provide near-term benefits to residents.

Current Research

ARB-funded research on Sustainable Communities aims to understand the climate, air quality, and societal (health, economic, equity) implications of the various land use and transportation planning strategies being pursued to meet SB 375 goals. These research projects seek to improve estimates of vehicle miles traveled, greenhouse gas emission reductions, and air pollution exposure. A handful of projects are examining how human behavior influences emission reductions (e.g., related to energy use in buildings and use of transit). 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.

A number of related research efforts are ongoing in California. The California Energy Commission is funding several projects at UCLA to study transit infrastructure and the impact of land use on energy systems. The Center for Resource Efficient Communities at UC Berkeley has produced white papers on a range of topics, including barriers to complete street design, factors affecting the success of SB 375, and future research priorities. The Urban Land Use and Transportation Center at the UC Davis Institute of Transportation Studies continues to develop statewide land use, transportation, and economic models to aid planning efforts. The Urban Land Use and Transportation Center is also conducting a variety of studies to advance policy design and behavior research, including research on building occupant behavior strategies to increase energy efficiency and the effects of policies on travel behavior and vehicle miles traveled. Caltrans has related research efforts focused on improving tools and data used in land use/transportation planning, advancing Bus Rapid Transit, exploring innovative travel options and Transportation Demand Management strategies, and understanding factors influencing non-motorized travel. ARB works closely with Caltrans to coordinate these efforts.

Research Needs

As California's built environment transforms in response to SB 375 and other policies, there are opportunities to assess the benefits and potential for unintended adverse impacts. Research to identify strategies and solutions to support the creation of healthier, more sustainable communities in California is needed.

In response to concerns about displacement of lower-income residents near transit-oriented development zones, two MPOs have begun to explore the issue. The Southern California Association of Governments (SCAG) developed a methodology to track demographic changes over time in areas designated as key growth areas; however, this method does not estimate potential impacts of their plans and cannot assess the potential displacement impacts of the land use scenarios they consider. The Association of Bay Area Governments (ABAG) and the Metropolitan Transportation Commission (MTC) analyzed risk of displacement among the five scenarios they were considering by identifying areas with a high percentage of financially strained renters and high percentage of projected growth. Neither of these methods takes into account the type and magnitude of transit and development investment nor do they address market conditions and other complex factors. As a result, the potential impact of transit-oriented development on displacement needs to be more comprehensively evaluated, and solutions need to be identified.

Reducing traffic pollution exposure for communities currently living near freeways is critical to improving the health of nearby residents. Traffic pollutant concentrations near high traffic roadways have been found to be two to 10 times higher than levels at a distance from the roadways. Recent studies have shown elevated traffic pollutant levels at greater distances from the roadway than previously measured. The State's current set-back requirement for schools (500 feet; PRC 21151.8) and ARB's recommendations on siting for housing and other sensitive uses (e.g., 500 feet from major roadways and 1000 feet from busy distribution centers and rail yards) are intended to help protect the public from exposure to traffic emissions. Various exposure mitigation approaches,

such as high efficiency filtration in homes and vehicles, are being examined as potential 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.

Proposed Projects

The two proposed projects will provide research to support ARB's goal to integrate and balance air quality, climate, and societal goals.

- Social Equity in Sustainable Communities Strategies
- Effectiveness of Sound Wall-Vegetation Combination Barriers for Near-Roadway Pollutant Mitigation

Social Equity in Sustainable Communities Strategies

Objective: As SB 375 fosters transit-oriented development to reduce greenhouse gas emissions, research is needed to understand and mitigate any unintended social equity impacts, such as the displacement of current low-income residents. The objective of this project is to promote the State goal of social equity in the integrated regional plans that address transportation, land use, and housing patterns.

Concept: SB 375 requires MPOs in California to develop a SCS that demonstrates how they will meet regional greenhouse gas reduction targets set by ARB, and many regions are including transit-oriented development among their strategies. Transit-oriented development is anticipated to reduce greenhouse gas emissions and achieve other health co-benefits, but improving transit services and concentrating growth around transit services may lead to unintended social equity impacts, including the direct and indirect displacement of current low-income residents. In response to these concerns, two MPOs have begun to explore issues of displacement in their first round of SCSs. SCAG developed a method to track demographic changes over time in key growth areas, but this method cannot assess the potential displacement impacts of the land use scenarios they consider. ABAG/MTC analyzed risk of displacement among five scenarios they were considering by identifying areas with a high percentage of financially strained renters and high percentage of projected growth. Ideally, analysis of social equity impacts should attempt to account for the type and magnitude of transit and development investment and address market conditions and other complex factors. To more fully address the potential adverse effects of future Sustainable Communities Strategies on social equity, a stronger understanding of the potential for displacement, including the ability to estimate the potential magnitude of displacement, and the identification and evaluation of solutions, is needed. To address this need, this project will advance our understanding of the relationship between transit-oriented development and displacement, including modeling past patterns of neighborhood change; create

regional model improvements and an off-model displacement assessment methodology to inform the planning process; and identify solutions that can be employed in California to reduce the potential adverse displacement effects. This project will advance the goal of ensuring that low-income communities share in the benefits of transit-oriented development. The results will be useful to MPOs and local and regional governments in California by providing them with information to help them evaluate and adopt transportation and land use strategies to minimize displacement.

Proposed Funding: $650,000

Effectiveness of Sound Wall-Vegetation Combination Barriers for Near-Roadway Pollutant Mitigation

Objective: Unhealthful levels of air pollution near roadways remain a long-term problem. Meaningful guidance is needed on approaches to reduce near-roadway traffic pollution exposure for communities currently living near freeways. The goal of this research is to evaluate the effectiveness of sound wall-vegetation barriers in mitigating air pollution exposures for residents near highly trafficked roadways.

Concept: Exposure to traffic emissions has been associated with a variety of serious health impacts, and children appear to be particularly vulnerable to the adverse effects. Various policies are in place to reduce air pollution exposure (i.e., set-back requirement for schools, CEQA mitigation requirements, and recommendations on siting for housing and other sensitive uses), and ARB has several contracts in place that are examining the effectiveness of filtration in homes and vehicles to reduce air pollution exposure. Sound walls and sound wall-vegetation barriers have also shown promise for reducing near-roadway pollutant concentrations. Studies have shown sound walls alone may reduce near-roadway pollution exposure by fifty percent, but further research is needed that identifies the specific conditions under which sound walls in combination with vegetation can reliably provide an exposure reduction benefit to California residents. This research will evaluate the variability, effectiveness, and possible disbenefits (e.g., some studies show an increase in pollution concentrations on-road and at a distance) of these barriers in various urban settings and meteorological conditions. For this project, researchers will identify the properties of roadside sound wall-vegetation combinations near residential areas, which will include different types of vegetation typically found in California. This information will be used to select multiple study sites in different geographical areas in California in order to understand the impacts of physical characteristics and meteorological conditions on near-roadway exposure. The study will also evaluate the effectiveness of sound wall and vegetation barrier combinations at multiple distances from the roadway. Researchers will conduct a multi-day pilot field study of at least one of the candidate sites to test and finalize sampling methods and protocols. Sampling will include real-time field measurements of traffic-related pollutants, meteorological data, traffic activity patterns, and noise measurements. Results of this research will present the air quality and exposure impacts of sound wall vegetation combinations, and will be used to inform the development of future exposure reduction strategies.

Proposed Funding: $500,000

PROGRAM EFFECTIVENESS

ARB regulations reduce atmospheric levels of pollutants that are harmful to human health and contribute to climate change. In designing and assessing regulatory programs, ARB considers their effectiveness in reducing emissions of ozone and PM2.5 precursors, toxic air contaminants, and greenhouse gases.

CURRENT RESEARCH

The ARB has a long history of conducting and sponsoring research to assess the air quality benefits of regulatory programs. Much of the current assessment of program effectiveness is focused on heavy-duty trucks and passenger cars. Remote sensing and tunnel studies of on-road vehicles have been conducted in the state for over two decades to measure the air quality improvements associated with increasingly stringent criteria pollutant emissions standards. These studies have been instrumental in refining emissions inventories and models used in development of regulations designed to attain federal air quality standards and reduce near-source exposure to toxic pollutants. More recently, ARB performed community monitoring to demonstrate the emission reductions and air quality improvement resulting from regulations to retrofit or replace diesel trucks with cleaner technologies. Last year's Research Plan included two projects to research the long-term durability and degradation rates of heavy-duty diesel aftertreatement, specifically diesel particle filters and selective catalytic reduction. This will be accomplished using measurements of emissions from the in-use fleet in tunnels and at weigh-in-motion stations in California. A third project from last year's Research Plan continues 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.

RESEARCH NEEDS

ARB's Truck and Bus Rule requires almost all heavy-duty 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 heavy-duty diesel vehicles. As mentioned above ARB has research projects in place to evaluate how well these aftertreatment controls perform in the real world over time. However, SCR requires minimum temperatures of almost 200 degrees Celsius before any NO_X can be reduced, which requires an understanding of cold starts and low-load operation in the heavy-duty diesel fleet to determine the overall effectiveness to SCR in reducing NO_X from heavy-duty diesel vehicles.

PROPOSED PROJECT

ARB proposes funding one project to constrain real-world emissions from heavy-duty trucks operating in California. Results from this project will improve emissions forecasts and provide insights into the effectiveness of selective catalytic reduction.

- Activity Data from On-road Heavy-duty Diesel Vehicles

Activity Data from On-road Heavy-duty Diesel Vehicles

Objective: The objectives of this research are to improve understanding of the real-world effectiveness of SCR for reducing emissions from heavy-duty trucks, and to evaluate whether certification test cycles are representative of how heavy-duty trucks are actually used.

Concept: Significant new reductions in NO_X emissions are required for California to meet federal air quality standards for ozone and PM2.5. Many of these reductions are expected to be achieved through the 2010 NO_X emission standard for heavy-duty on-road engines. Diesel engine manufacturers are in most cases using advanced engine exhaust aftertreatment, specifically SCR, to meet the new standard. In order to be effective, SCR requires adequate temperatures (typically at least 200 degrees Celsius) for NO_X reduction to take place, but there are times when this temperature requirement is not met, such as right after engine start and during low loads experienced when the engine is idling, or when the vehicle is moving slowly on flat terrain. The frequency of low temperature and low-load operations varies for a truck depending on its use (line haul, drayage, delivery, etc.), and it is therefore critical to characterize heavy-duty diesel truck activity including duty cycles, number of engine starts, and engine soak time distributions. This research will include a screening analysis to identify the magnitude of NO_X emissions for various heavy-duty trucks' uses. Researchers will then conduct a truck travel survey with global positioning system data loggers to quantify the number of engine starts and the soak time distribution, and will also collect engine control unit or on-board diagnostic data to develop truck activity profiles for various uses. The analysis will be used to evaluate the representativeness of the certification cycle compared to real world emissions of NO_X for the different types of heavy-duty vehicles. The results will be used to improve heavy-duty NO_X emissions models, and to assess whether certification and compliance procedures need to be modified.

Proposed Funding: $400,000

NEXT STEPS

The nine research projects proposed in this plan address key knowledge gaps and will strengthen the scientific foundation of 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.