Annual Research Plan

Fiscal Year 2012-13

June 2012

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.

This year's annual plan includes projects that will increase understanding of California's progress on air quality, answer near-term questions important for program implementation, and explore benefits of longer-term strategies. ARB's research program will continue to play an important role in meeting the challenges of increasingly stringent federal 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.

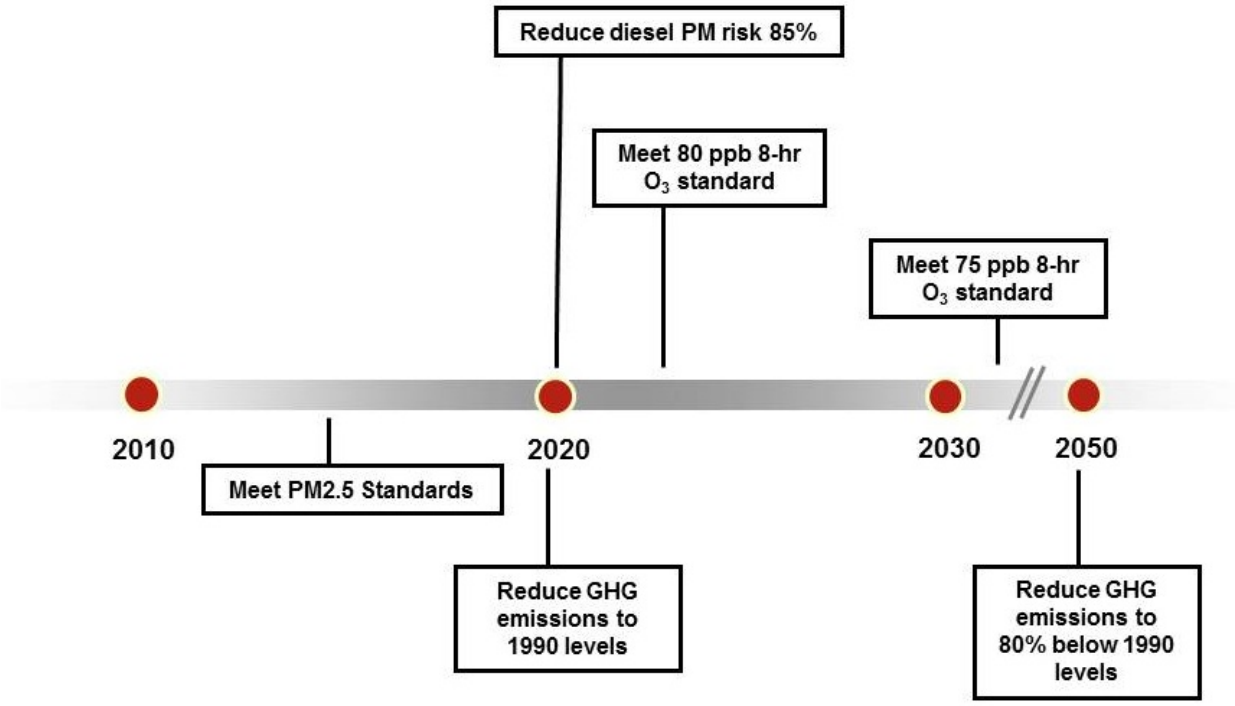

Figure 1. California's key air quality and climate change milestones through 2050.

This research plan is designed to reflect the highest priority program needs. Although this year's plan is largely focused on near-term program needs (i.e., next 5 to 10 years), several projects have implications for assessing long-term transportation and land use strategies.

This plan is organized around three overarching research themes: scientific foundation, clean air strategies (comprising mobile source and sustainable communities strategies), and program effectiveness:

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

Clean Air Strategies – Addressing both mobile source control and sustainable communities strategies, 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 measurement and evaluation efforts to verify that its regulations are effectively meeting their targets and protecting public health.

The Fiscal Year 2012-2013 Research Plan includes 14 research concepts, totaling approximately $6 million, for which ARB intends to obtain significant co-funding. As shown in Figure 2, the majority of the research funding is allocated to research related to mobile sources (52%) with the remaining funds supporting research related to scientific foundation (21%), sustainable communities (19%), and program effectiveness (8%).

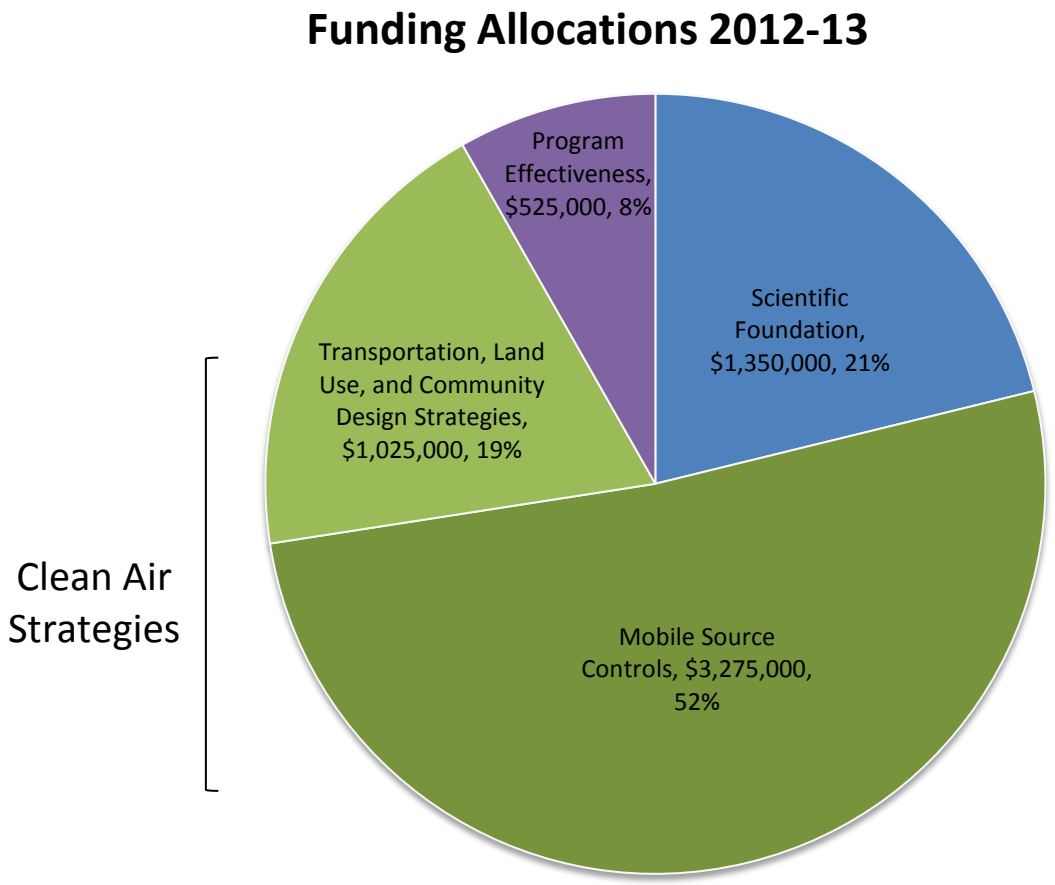

Figure 2. Proposed ARB research funding allocation for fiscal year 2012-2013.

PLANNING PROCESS

This research plan is designed to address the Board's highest priority program needs. As in previous years, ARB initiated the research planning process by sending out a public solicitation inviting and encouraging the public to contribute research concepts that address ARB's priority research areas. This year's research planning also benefited from ongoing discussions with experts from multiple government agencies and other institutions with scientific expertise or regulatory authority in air pollution and related fields. ARB staff prioritized specific program needs, reviewed research ideas submitted by the public, developed additional research concepts to address remaining program needs, and synthesized the results to produce this annual research plan. Pending approval by the Board, the research projects described in this plan are ready to be developed 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 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 co-funding opportunities and other ways to leverage limited research dollars. This enables ARB to participate in projects and studies outside the reach of ARB's research budget alone. Research partners have included a wide range of government agencies and research organizations including, but not limited to, the U.S. Environmental Protection Agency (EPA), the National Oceanic and Atmospheric Administration (NOAA), the National Aeronautics and Space Administration (NASA), the Coordinating Research Council (CRC), the California Energy Commission (CEC), the California Public Utilities Commission (CPUC), the California Department of Transportation (Caltrans), the Health Effects Institute (HEI), and the South Coast Air Quality Management District.

This year's annual research plan will leverage multi-million dollar funding commitments from NASA and the National Institute of Standards and Technology (NIST) to study California's air quality and greenhouse gas emissions. ARB is also coordinating with the U.S. EPA and the National Highway Traffic Safety Administration (NHTSA) on the mid-term review of ARB's Advanced Clean Cars rules, and is exploring co-funding opportunities for related projects. And, in order to verify compliance with the Advanced Clean Cars rules, this plan includes co-funding for a CRC project that seeks to lower the detection limit of particulate matter (PM) emissions.

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 completed over the past year have added to the body of evidence on the impacts of particulate matter and ozone exposure on public health. For the first time, exposure to particulate matter (PM10) has been associated with the incidence of new cases of stroke in California women. In another California study, fine particulate matter (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 activate cells that initiate blood clotting, which can result in an increased risk of heart attacks and stroke. A toxicologic study conducted in the San Joaquin Valley (co-sponsored by ARB and the Electric Power Research Institute) confirmed epidemiologic studies in finding that no specific source of PM2.5

appears to be less toxic than any other – reaffirming the need to continue to regulate all sources of fine particles. 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 positive 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 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 last year to investigate the effectiveness of high-efficiency filtration in reducing pollution exposures for asthmatics, as well as in homes, school buses, and cars. Results from these research projects are expected in 2015 and 2016.

Clean Air Strategies

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 PM 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 nitrogen dioxide (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 in California 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 sources of other important non-CO_2 greenhouse gases, such as methane (CH_4) and nitrous oxide (N_2O), in California 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. In addition, ARB and NOAA have been collaborating on a major field campaign to examine climate and air quality impacts in California. The first major published result from this study demonstrates that California's first-in-the-nation regulations for ocean-going vessels to 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

SCIENTIFIC FOUNDATION

Attainment of health-based national and state 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 2011, the eight-hour design value was reduced to 0.107 ppm with about 100 exceedance days.

CURRENT RESEARCH

The Board has long been a pioneer in funding studies of air pollution's health effects. 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 both national and state 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. These types of publications are of value in standard reviews and help provide evidence for the basis that U.S. EPA uses to select the concentration and averaging time for the 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 emissions change over time. And as air quality standards are tightened and emissions from California sources decline, the contributions of long-range transport of pollution from Asia and intrusion of stratospheric ozone will need to be better understood. Recognizing that these issues cannot be solved alone, ARB has collaborated with national and international agencies on a wide variety of atmospheric studies. For example, ARB and NOAA recently partnered on the 2010 CalNex study[1] to research key air quality questions, to study emissions of greenhouse gases, and to explore the nexus between air quality and climate change issues (e.g., black carbon). ARB is also partnering with NASA on two new major efforts, beginning in 2012, to use their advanced satellite and modeling capabilities to further investigate these issues.

In 2006, with the adoption of the Global Warming Solutions Act (Assembly Bill 32 or AB 32), ARB's research program expanded to include sources and potential mitigation strategies for greenhouse gases. Over the past five years, ARB has inventoried California's sources of high-global warming potential industrial gases (e.g., refrigerants,

[1] A synthesis of the CalNex results will be completed by NOAA in 2013.

insulation foam-blowing agents), partnered with the CEC and the California Department of Food and Agriculture (CDFA) on a comprehensive research program to examine N_2O emissions related to the application of fertilizer to agricultural soils, established a regional monitoring network to measure statewide emissions of CO_2, N_2O and CH_4, and deployed two mobile monitoring platforms to better understand specific sources of greenhouse gases. Beginning in 2012, ARB intends to use its existing greenhouse gas monitoring network and research tools to complement a five-year greenhouse gas monitoring project funded by NIST to investigate the sources and trends of CO_2 and CH_4 emissions in Los Angeles.

Research Needs

Despite improvements in California's air quality, ozone and particulate matter levels continue to exceed health-based air quality standards in both urban and downwind rural areas of California. While the causes of high urban ozone levels have been studied for decades, it is very complex – involving thousands of compounds that react in a nonlinear fashion – and the state of scientific knowledge is constantly evolving and improving. Continuing to improve the photochemical mechanisms and data inputs used in air quality models is a priority since these models are required to be used to demonstrate compliance with federal standards.

The sources and formation of PM2.5 has become an increasingly important research area since the first federal PM2.5 standard was set in 1997. Although NO_X and diesel PM controls have led to significant emission reductions and lower atmospheric PM2.5 levels, the organic carbon component (about 25 percent of PM2.5) is less well understood. Preliminary data from CalNex and other studies indicates that more research is needed to fully characterize organic carbon in air quality models and that organic carbon's role in climate change may be much greater than previously thought.

Proposed Projects

ARB plans to leverage a multi-million dollar commitment by NASA to study air quality in California next year with three proposed projects focused on the organic carbon fraction of PM2.5. These projects will provide essential information on emissions, atmospheric transformations, and the role of the organic carbon fraction of PM2.5 in climate change. In addition, one of the proposed projects will also provide an updated chemical mechanism for ozone formation.

- Improving Controls and Measurement Methods for Semi-Volatile Organic Compound Emissions from Light-Duty Vehicles
- Improving Chemical Mechanisms for Ozone and Secondary Organic Carbon
- Characterizing the Climate Impacts of Brown Organic Carbon

Improving Controls and Measurement Methods for Semi-Volatile Organic Compound Emissions from Light-Duty Vehicles

Objective: Results from recent research indicate that light-duty gasoline vehicles emit significant amounts of semi-volatile organic compounds that, in turn, form secondary

organic carbon in the atmosphere. The objectives of this project are to: 1) study possible control technologies to reduce semi-volatile organic compound emissions from light-duty vehicles, and 2) explore more cost-effective measurement technologies to quantify semi-volatile organic compound emissions from light-duty vehicles.

Concept: Public exposure to particulate matter air pollution is associated with adverse health effects such as asthma and premature mortality. Contributions to ambient particulate matter are caused by two sources: directly emitted particulate matter, such as vehicle tailpipe emissions, and secondary organic carbon formation in the atmosphere, from precursor emissions such as semi-volatile organic compounds. Light-duty vehicles are known to be relatively small contributors to directly emitted particulate matter, but a recent research project reveals that these same vehicles also emit semi-volatile organic compounds that result in secondary organic carbon formation. As part of this same research project, old and late model heavy-duty diesel trucks were also tested, and results show that diesel engine aftertreatment effectively controls semi-volatile organic compound emissions. These results suggest that diesel engine emissions control technologies can potentially serve as a model for possible control of semi-volatile organic compound emissions from light-duty vehicles.

In the proposed study, prototype control technologies, such as improved catalytic converters or gasoline particulate filters, will be installed on selected test vehicles and emissions testing will be conducted to determine control technology effectiveness. In addition to vehicle tailpipe emissions controls, this project will investigate the emissions impacts of changes to gasoline composition, such as increased ethanol content. Semi-volatile organic compound emissions are not routinely measured as part of the current certification procedures, but such measurements would be needed as part of a possible control program. These emissions are regularly measured during field studies of ambient aerosols, and field techniques will be studied and evaluated for incorporation into vehicle testing procedures. Results from this project will determine the technical feasibility and potential emissions reductions from control of semi-volatile organic compound emissions from light-duty vehicles, and will also determine the most accurate and cost-effective method for measuring these emissions.

Proposed level of funding: $500,000

Improving Chemical Mechanisms for Ozone and Secondary Organic Carbon

Objective: Photochemical air quality models are required to be used as part of the foundation for air quality plans and to assess the relative effectiveness of air pollution control strategies to achieve federal standards for ozone and PM2.5. This project will develop updated chemical mechanisms for predicting the formation of ozone and secondary organic carbon, and assess the reactivity of volatile organic compounds in California's airsheds. The results of this study will be used by ARB to update atmospheric chemistry in models used for air quality planning.

Concept: Photochemical mechanisms used in air quality models should represent the most up-to-date understanding of how ozone and the secondary organic carbon fraction of PM2.5 are formed and their relationships to the primary pollutants emitted from

different source categories. The SAPRC chemical mechanisms (named after the Statewide Air Pollution Research Center) have been developed or updated under ARB's sponsorship for more than 20 years and extensively used in regulatory and scientific modeling applications for ozone and PM2.5. The current version of the SAPRC gas-phase mechanisms is SAPRC-07, which represents the state of the science as of 2007. There have been significant developments in several areas that warrant an update of the chemical mechanisms, since ARB will continue the use of SAPRC for regulatory applications in California. A recently completed project added a chemical mechanism for secondary organic carbon into SAPRC-07.

The proposed research will continue development of secondary organic carbon chemical mechanisms with the goal of improving predictive models for secondary organic carbon formation from aromatics and other volatile organic compounds. This project will update model scenarios to improve estimates of the ozone-forming potential of volatile organic compounds and develop optimal condensed mechanisms for airshed models to reduce computer time without sacrificing accuracy. The researchers will also perform sensitivity analysis of organic nitrate and dinitrogen pentoxide chemistry on the formation of secondary pollutants, taking into account recent laboratory and field studies (e.g., CalNex), and conducting modeling simulations for typical summer and winter pollution episodes in California's major air basins. The results of this research will provide the ARB with improved and more up-to-date mechanisms for ozone and secondary particulate matter prediction and volatile organic compound reactivity assessment.

Proposed level of funding: $450,000

Characterizing the Climate Impacts of Brown Organic Carbon

Objective: Black carbon (the dark soot produced from combustion) absorbs light and gives off heat, and is now recognized as a significant contributor to global warming. Light-absorbing organic carbon that is not black, called brown carbon, was recently discovered to also be a potentially large contributor to global warming. The proposed research will characterize the extent to which brown carbon contributes to light absorption in California, which will help improve understanding of the contribution of brown carbon to global climate change.

Concept: A better understanding of the relative contribution of brown carbon to atmospheric warming will allow its effects to more accurately be captured in climate models. Although the optical properties of black carbon are relatively well understood, those of brown carbon are more uncertain. Research indicates that brown carbon, which is believed to consist of higher-molecular weight hydrocarbon compounds, absorbs more strongly and primarily at shorter wavelengths (i.e., blue and ultraviolet), whereas black carbon absorbs all wavelengths of solar radiation far more effectively than brown carbon and therefore has a greater warming effect, by mass. Although brown carbon absorbs less energy per unit mass than black carbon, some sources of both (such as open biomass burning) can produce substantially more brown carbon than black carbon, so the quantity of brown carbon may lead to more warming than that

caused by black carbon. Some studies indicate that brown carbon may account for as much as 20 percent of the solar radiation absorbed by the earth's atmosphere.

The combustion sources that contribute to brown carbon in the atmosphere are not well characterized, and recent studies suggest that there may be multiple pathways for its formation. To help characterize and differentiate sources of brown carbon from black carbon, the proposed research will make source-specific chemical and multi-wavelength optical measurements of particulate matter at several monitoring sites in California. The investigators will quantify chemical and optical characteristics of brown carbon sources and investigate the formation pathways for brown carbon. The results will be analyzed and the impact of brown carbon on atmospheric warming will be estimated using California data.

Proposed level of funding: $400,000

CLEAN AIR STRATEGIES

CLEAN AIR STRATEGIES

Supporting the development of clean air strategies remains a cornerstone of ARB's research program. The focus has historically been on the transportation sector where ARB has primary authority, and this research will continue, focusing on light-duty vehicles and freight transport. When AB 32 was enacted in 2006, ARB's research program expanded to include studies ranging from high-global warming potential industrial gases to voluntary strategies based on climate-friendly behavior. Research needs in other sectors (e.g., energy efficiency, renewable energy) have largely been addressed by other state agencies including the CEC and CPUC.

ARB's research efforts have led directly to some of the regulations and programs now in place to meet the 2020 greenhouse gas emission goals of AB 32. The enactment of the Sustainable Communities and Climate Protection Act of 2008 (Senate Bill 375 or SB 375) pushed ARB's research program further into 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, and a transition to zero and near-zero emission technologies.

MOBILE SOURCE CONTROL STRATEGIES

Passenger travel and freight transport are major sources of both criteria and toxic air pollutants and greenhouse gas emissions in California. To meet long-term air quality and climate goals, emissions from these sectors will need to be significantly reduced beyond what is expected from already adopted regulations.

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, and NO_X emission standards for cars, and 90 percent reductions in particulate matter and NO_X emissions from new trucks. 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 fleet and emissions. Research on NO_X emissions from heavy-duty diesel engines is ongoing in Europe, at ARB and the U.S. EPA to characterize the in-use emissions from trucks employing selective catalytic reduction aftertreatment, to address questions related to in-use versus certification emission levels, and the need for certification methods appropriate for selective catalytic reduction. Rail electrification research, funded by Caltrans, LA Metro, and the Southern California Association of Governments, has focused on engineering or technical aspects while economic issues were generally noted as an area for future investigation.

RESEARCH NEEDS

Continued advancements in technology necessitate ongoing research to ensure that the expected emission benefits from existing and future regulatory programs are realized. The recently approved Advanced Clean Cars program requires a midterm review, coordinated with U.S. EPA and NHTSA, to evaluate whether the regulations will achieve the expected emissions reductions from the light-duty fleet.[2] To support the midterm review, additional research is needed to quantify the electricity powered miles driven by advanced technology vehicles, to understand the charging behavior of electric vehicle drivers, to develop methods for measurement of low levels of particulate matter emissions so that compliance can be reliably determined, and to quantify the emission benefits of vehicle load reduction. Research in these areas will be coordinated with U.S. EPA and NHTSA.

NO_X emissions remain a challenge to meeting health-based air quality standards. It is an important precursor for both ozone and particulate matter, and upcoming federal deadlines for ozone and fine particulate matter (PM2.5) standards cannot be met without substantial new reductions. In 2010, the heavy-duty engine emission standard for NO_X was lowered by 90 percent. Nevertheless, heavy-duty trucks will continue to be a significant contributor to overall NO_X emissions in the state, and recent ARB in-house research indicates that there is potential for further NO_X reductions.

Research is also needed to help develop effective strategies for reducing not only NO_X, but also diesel particulate and greenhouse gas emissions from the freight system. Achieving zero or near zero emissions from railroad operations in California will require advanced technologies, such as cleaner locomotive engines and fuels, but very likely also operational changes in the rail system both within California as well as nationally. These technological and operational improvements require a better understanding of economic costs, as well as potential long-term savings, so that the most cost-effective strategies can be identified.

PROPOSED PROJECTS

The five research projects proposed for mobile source control strategies reflect new program needs, long-term goals, and build on the comprehensiveness of California's existing clean air strategies research program.

- Economic and Operational Considerations in Transitioning to a Zero or Near-Zero Emission Rail System in California
- Evaluating Technologies and Methods to Lower NO_X Emissions from Heavy-Duty Vehicles
- Advanced Plug-in Electric Vehicle Travel and Charging Behavior
- Technical Analysis of Vehicle Load-Reduction Potential for Advanced Clean Cars
- Improving Detection of PM Emissions for Certification of Advanced Clean Cars

[2] During the midterm review, ARB will also evaluate the possibility of accelerating the phase-in schedule of particulate matter standards and assess progress to date on the other components of the program.

Economic and Operational Considerations in Transitioning to a Zero or Near-Zero Emission Rail System in California

Objective: Meeting California's long-term air quality, public health, and climate goals will require transitioning to a zero or near-zero emissions freight transport system, including rail operations. The proposed study will examine the economic challenges and opportunities, as well as operational changes, involved in transitioning to zero or near-zero emission rail operations both in California and nationally.

Concept: ARB's recently adopted diesel regulations addressing drayage trucks, cargo handling equipment, and transport refrigeration units are significantly reducing diesel particulate matter emissions and health risk in the vicinity of California's rail yards. As a result, by 2020, more than 75 percent of remaining rail yard emissions in California is expected to come from diesel-powered line haul locomotives.

In order to further reduce health risks in communities adjacent to the rail yards while also achieving necessary criteria pollutant and greenhouse gas emissions reductions, California will need to transition to a zero or near-zero emissions locomotive fleet. This will most likely be accomplished through some combination of tighter emission standards for diesel locomotives, use of cleaner biofuels, hybridization and/or electrification of locomotives, accelerated deployment of the cleanest locomotives to California, and more efficient railroad logistics and operations. To date, studies of the technological feasibility of rail electrification have been funded by Caltrans, LA Metro, and the Southern California Association of Governments. ARB staff are continuing this technological assessment but also looking more broadly at all types of zero or near zero technologies, as well as the use of cleaner fuels.

However, the assistance of external researchers with expertise in rail economics and operations is needed for ARB staff to fully assess the feasibility of different approaches for achieving zero or near-zero rail emissions. The proposed research project will assess current railroad economics and operations, including California and the national rail system, as well as an assessment of a range of future scenarios developed with the guidance of ARB staff.

The business costs examined in this study will need to extend beyond just the cost of new locomotives and infrastructure to include other economic as well as operational issues including: 1) the potential benefits of fuel savings associated with fleet modernization and optimization of rail operations; 2) possible use of existing railroad rights-of-way to construct renewable energy (solar or wind) facilities that could be used to support rail electrification with the possibility of selling excess power to offset costs; 3) and the impacts on business operations, including potentially increased costs, associated with a California-specific locomotive fleet or additional railcars to transport batteries or other power sources. These and other issues will be more fully defined when the full scope of work for this project is developed.

Proposed level of funding: $400,000

Evaluating Technologies and Methods to Lower NO_X Emissions from Heavy-Duty Vehicles

Objective: The objective of the research is to find technologies, tuning and engine management practices that will enable heavy-duty natural gas and diesel vehicles to meet NO_X emission rates significantly lower than the 2010 emissions standard. While the purpose will be to establish the lowest emission rate possible, the goal will be to achieve at least a 90 percent reduction compared to the 2010 standard. The NO_X reductions should be achieved without an overall greenhouse gas penalty, at a minimum, and preferably with a concurrent greenhouse gas emission benefit.

Concept: The 2010 NO_X emission standard for heavy-duty engines, limiting NO_X to 0.2 grams per brake horsepower-hour, constitutes a 90 percent reduction in emissions. Nevertheless, upcoming federal air quality standards for particulate matter and ozone cannot be achieved in California without significant additional NO_X emissions reductions from the heavy-duty fleet beyond what will be achieved with a 2010 compliant fleet. The main technology employed by diesel engine manufacturers to meet the 2010 engine NO_X standard is selective catalytic reduction which reduces engine-out NO_X prior to emission at the tailpipe. In natural gas trucks, selective catalytic reduction is typically used in lean burn engines while three way catalysts are used in stoichiometric engines. These are relatively new technologies in heavy-duty truck applications and manufacturers of selective catalytic reduction, three way catalysts, and heavy-duty engines are applying the lessons learned in earlier applications, such as stationary sources and light duty vehicles, to optimize the overall systems to achieve the required NO_X reductions. However, as these methods mature, meeting NO_X emissions standards below the 2010 level should become possible in heavy-duty truck applications.

The proposed research aims to optimize the aftertreatment technology choice, aftertreatment configuration, urea dosing strategies, and engine tuning to maximize NO_X emissions reductions beyond levels needed to meet the existing standard in the following three heavy-duty applications:

1. Heavy duty diesel vehicles with selective catalytic reduction
2. Lean burn natural gas with selective catalytic reduction
3. Stoichiometric natural gas with three way catalysts

In the proposed study, the level of emissions reduction possible will be established through testing on an engine dynamometer test bench. Results of this research will be helpful in developing tighter NO_X emissions standards for heavy-duty engines that will be needed if California is to meet more stringent federal air quality standards.

Possible co-funding: Co-funding for this project will be sought from U.S. EPA, the South Coast Air Quality Management District, and the Manufacturers of Engine Control Association. Without co-funding the project will likely have to be scaled back and prioritized to reduce the overall cost.

Proposed level of funding: $2,000,000

Advanced Plug-in Electric Vehicle Travel and Charging Behavior

Objective: Electric-drive vehicles are expected to account for an increasingly large share of new light-duty vehicle sales as the Advanced Clean Cars program is implemented. However, the actual air quality benefits associated with turnover to these vehicles could vary depending on individual consumer usage and charging behavior. The objective of this research project is to collect and analyze longitudinal, in-use vehicle data, including electric vehicle miles traveled, that will improve criteria and greenhouse gas emission estimates of individual vehicles types as well as the on-road fleet as a whole.

Concept: Emissions benefits from plug-in electric vehicles will depend on real-world driving conditions and how many miles these vehicles are driven using on-board power sources. How consumers will use and charge vehicles is not well understood, especially given the diversity of expected vehicle designs and electric driving ranges.

Research by the Plug-in Hybrid Electric Vehicle Center at the University of California (UC) at Davis has evaluated usage and charging behavior of a small sample of blended plug-in hybrid electric conversions based on longitudinal instrumented vehicle data and household interviews. In another study, the CEC will collect on-board vehicle information from approximately 250 owners of Chevrolet Volt and Nissan Leaf vehicles in California for a one-week period. The results of the CEC study will be used to evaluate how energy usage differs between these two vehicle models as well as compared to other conventional vehicles in the study households. Both the UC Davis and CEC research studies are expected to provide useful, practical experience for collecting and analyzing vehicle operation, usage, and charging data, but these studies alone will not be sufficient to draw robust conclusions on the variation between vehicle types. Additionally, DOE is collecting usage data from thousands of plug-in hybrid electric and full battery electric vehicles placed throughout the country which may provide comparative results.

In the proposed ARB study, the investigators will analyze manufacturer submitted vehicle data for different vehicle types to estimate the share of a vehicle's miles traveled that emits zero tailpipe emissions. To supplement this analysis, the researchers will also recruit a stratified sample of plug-in electric vehicle-owning households and instrument all vehicles within the household to evaluate the emissions profile of total household vehicle miles traveled and charging behavior. The results of this study will be used to refine estimates of the emissions benefit of different designs of plug-in electric vehicles (plug-in hybrids, range extended battery electrics, and full battery electric vehicles). The travel pattern and charging behavior findings will help improve emissions inventory models, especially for advanced vehicles, and also inform estimates for electricity demand and grid management as well as siting of new public charging infrastructure.

Proposed level of funding: $650,000

Technical Analysis of Vehicle Load-Reduction Potential for Advanced Clean Cars

Objective: To meet stringent new vehicle emission standards, manufacturers are expected to consider additional vehicle load-reduction strategies such as improved aerodynamics, reduced tire rolling resistance, or mass optimization. The objective of this research project is to understand the maximum potential usage of these types of strategies by vehicle manufacturers assuming that all model year 2025 vehicles adopt today's best-in-class load-reduction technologies.

Concept: The Advanced Clean Cars program requires the new vehicle fleet to meet increasingly lower fleet average greenhouse gas emission standards. Greater penetration of load-reduction technologies, such as improved aerodynamic designs, low rolling resistance tires, and mass optimization, is likely to be a core component of auto manufacturers' strategies for complying with the tighter greenhouse gas emission standards. Previous ARB-sponsored research by Lotus Engineering showed that it is feasible to reduce vehicle mass by over 30 percent without compromising passenger safety. Joint modeling efforts by ARB and U.S. EPA for light-duty vehicle greenhouse gas emission standards found it feasible and cost-effective to achieve an additional 20 percent reduction in vehicle mass, tire rolling resistance, and aerodynamic drag. The annual U.S. EPA model-by-model fuel economy and CO_2 emission certification data provides the fundamental physical parameters (i.e., road load coefficients) to analyze the extent to which load-reduction technologies are employed in currently available vehicles.

The proposed research project will analyze U.S. EPA certification data for 2012 and later model year vehicles to identify those vehicle model configurations with the best aerodynamic, tire rolling resistance, and mass optimization characteristics. Controlling for powertrain size, vehicle size, body style, and other vehicle attributes, the researchers will conduct a statistical analysis to quantify the potential of the leading emerging load-reduction technologies to achieve greenhouse gas reductions if deployed across all vehicle models in the expected 2020 to 2025 vehicle fleet. The researchers will also quantitatively assess the ability for the emerging load reduction strategies, if comprehensively deployed, to have ancillary cost benefits in terms of downsized powertrains for all vehicles and reduced energy storage (for hybrid, plug-in electric, and hydrogen fuel cell vehicles). The results of this project would help assess the technical feasibility and associated costs for advanced technology vehicles of all types as part of the midterm evaluation of the Advanced Clean Cars program.

Proposed level of funding: $150,000

Improving Detection of PM Emissions for Certification of Advanced Clean Cars

Objective: The ARB recently adopted lower tailpipe particulate matter standards for light-duty vehicles as part of the Advanced Clean Cars regulations (LEV III). The objective of this research project is to investigate possible modifications to improve the current gravimetric filter particulate matter measurement methods in light of these new standards.

Concept: The lowering of the light-duty vehicle particulate matter emissions standards, first to 3 milligrams per mile, and then to 1 milligram per mile, present measurement challenges using existing measurement methods. ARB in-house analysis indicates that particulate matter measurements at these low levels are feasible, but research is needed to confirm that these measurements are repeatable under standard certification testing conditions.

The CRC recently released a request for proposals for a research project to develop reproducible and acceptable test methods for measuring very low concentrations of particulate matter in vehicle exhaust (3 milligrams per mile), and to investigate possible methods to improve the repeatability of the current gravimetric particulate matter measurements procedures specified in the Code of Federal Regulations, Part 1066, including changes to emissions sample dilution, combining different phases of the test cycle on a single filter, changing filter face velocity, and other laboratory test methods and procedures. This project augments the CRC project, with the goal of achieving repeatable emissions measurements down to 1 milligram per mile. This research will improve existing measurement methods, thus addressing many of the questions regarding the feasibility of the lower particulate matter emissions standards for light-duty vehicles.

Proposed level of funding: $75,000

Transportation, Land Use, and Community Design Strategies

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 that demonstrates how they will meet regional greenhouse gas reduction targets set by ARB, or to do a plan showing what it would take to meet the targets. Three major MPOs in California have completed their first sustainable communities strategies that meet ARB targets and others are in progress. The strategy for the largest MPO, the Southern California Association of Governments, relies significantly on more compact transit oriented development to achieve reductions in per capita greenhouse gases and to reduce smog forming emissions. Other urban MPOs are also planning for enhanced transit oriented development.

Current Research

The ARB and other agencies are conducting research on the built environment, focusing on land use, transportation, community design, and energy efficiency. This includes exploring factors like economic and behavior patterns, and looking at the impact of built environment systems on energy use, human health, and the environment. CEC 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 understanding the effects of policies on travel behavior and vehicle miles traveled.

Ongoing ARB-funded research aims to improve vehicle miles traveled and greenhouse gas emission reduction estimates, determine the role of land use planning in reducing residential energy consumption, quantify greenhouse gas and criteria air pollutant emissions reductions associated with commercial green buildings, investigate the effects of complete streets on travel behavior, vehicle miles traveled, and public health, explore the economic costs and benefits of smart growth strategies, and quantify the effect of local government actions on reducing vehicle miles traveled.

Research Needs

As transportation, land use, and community design strategies are implemented, there are opportunities to assess the benefits and the potential for any unintended adverse impacts. Research is needed to evaluate the impact of light rail transit on choice of travel mode, including active transport such as walking and bicycling, as well as to assess whether increased exposure to traffic emissions might result. Pavement materials that absorb less of the sun's energy reduce urban heat islands, slow smog formation, reduce building energy use, and cool the Earth's atmosphere. Encouraging large-scale adoption of these cool pavement materials will require quantitative information on pavement performance and air quality impacts to assist decision makers in local transportation and planning agencies considering construction of new roadways and parking lots.

Proposed Projects

The three proposed address a variety of research issues related to urban design and transportation strategies.

- Identifying Urban Designs and Traffic Management Strategies that Reduce Air Pollution Exposure
- Evaluating Benefits for New Light Rail Transit Lines
- Life Cycle Assessment and Co-Benefits of Cool Pavements

Identifying Urban Designs and Traffic Management Strategies that Reduce Air Pollution Exposure

Objective: As more compact transit-oriented development occurs, it is important to assess the potential for unintended effects such as increased pedestrian and resident air pollution exposure, and to prevent or mitigate such effects to the extent possible. This project will improve the understanding of near-roadway exposures for a range of California urban landscapes and identify potential mitigation strategies to reduce air pollution exposures.

Concept: As communities include more higher density, transit-oriented development, research is needed to better understand street-level exposure and the potential for

urban designs and traffic management strategies to prevent or mitigate these exposures.

The street-level exposure studies that have been conducted lack the spatial resolution and focus on freshly emitted pollutants necessary to refine and validate dispersion models for urban landscapes in California. Previous studies that have focused on deep street canyons do not appropriately capture the lower, more variable and widely-spaced building stock typical of California. Also, there are no known tools to help urban and transportation planners incorporate pedestrian pollution exposure into transit-oriented development planning.

Using Los Angeles as a case study, this project will further refine an existing model that can be used, along with air pollutant and meteorological data collected as part of this study, to estimate California-specific air pollution exposures of pedestrians and residents living and traveling along transportation corridors with many bus stops. The collected data and model will also be used to quantify the effects of community design and traffic management choices on air pollution exposures, which will help inform design of future transit micro-environments in California. This project will help regional and transportation planners minimize pedestrian roadway pollution exposure as SB 375 is implemented.

Proposed level of funding: $375,000

Evaluating Benefits for New Light Rail Transit Lines

Objective: This research will advance the understanding of the impact of light rail on travel behavior. Opened in April 2012, the new Expo Line light rail in Los Angeles provides a unique opportunity to examine how light rail transit impacts travel behavior in California. The findings can be used to improve travel demand forecasting models used by metropolitan planning organizations in the SB 375 planning process. This study will expand the currently limited body of knowledge on the impacts of transportation infrastructure on walking and bicycling.

Concept: The regional travel demand forecasting models used by metropolitan planning organizations in the SB 375 planning process are limited in their ability to accurately evaluate smaller-scale smart growth and transit projects. The existing models are largely based on regional averages from cross-sectional travel surveys, and do not fully capture the local impact of land use and transportation strategies on travel behavior. Although the sustainable communities strategies developed under SB 375 have the potential to encourage active transport modes such as walking and bicycling, quantification of these effects is limited.

The proposed research study will build upon an existing study that assessed the travel modes of approximately 250 households in the vicinity of the planned Expo light rail line in Los Angeles. This existing study collected travel data including trip logs, odometer readings, and, for half of the households, GPS locations and measurements of physical activity for a seven-day period prior to the Expo Line being completed. The proposed project will collect similar data for the same 250 households now that the Expo Line is

operating to assess how access to this new mode of transit has affected the distribution of travel by mode choice. Results of this study are expected to help local governments and planning agencies better account for reductions in vehicle miles traveled and changes in other transportation mode choices related to construction of light rail infrastructure.

Proposed level of funding: $200,000

Life Cycle Assessment and Co-Benefits of Cool Pavements

Objective: Research is needed to quantify the potential air quality and climate benefits possible from use of cool pavements in California. The objective of the proposed research is to measure emissions of air pollutants and conduct life cycle assessments for different types of pavement materials commonly used in California, including asphalt and concrete, as well as new cool pavement technologies that are being considered.

Concept: Over 80 percent of pavements in California are various forms of asphalt. Asphalt, with one third the aged reflectance of concrete, warms local and regional climate, accentuating urban heat islands and associated population heat stress. In addition, asphalt is softer than concrete and has higher rolling resistance which leads to tire wear, reduced fuel economy, and higher greenhouse gas and criteria pollutant emissions from vehicles. In 2011, the ARB, CEC, and DOE funded Lawrence Berkeley National Laboratory to test a variety of cool pavements. This work, which is underway, will compare the temperatures, heat fluxes, and solar reflectance of four cool pavement technologies with those of two conventional technologies.

The proposed research project will build upon current pavement research by quantifying criteria pollutant and toxic emissions for different pavement technologies already being tested. The researchers will conduct life cycle analysis for greenhouse gases using input data collected from paving manufacturers and measured from several cool pavement demonstrations. These measurements will include emissions data; surface, air, and mean radiant temperatures; heat conduction; solar reflectance; and possibly ultraviolet reflectance and water permeability. Quantification of the air quality and life cycle impacts of these different pavement materials will provide information for state and local transportation and land use agencies to consider in the process of setting or revising pavement standards.

Proposed level of funding: $450,000

PROGRAM EFFECTIVENESS

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. 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.

RESEARCH NEEDS

Much of the current assessment of program effectiveness is focused on diesel vehicles and passenger cars. 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 in most late model heavy-duty diesel vehicles. How well these aftertreatment controls perform in the real world and over time needs to be evaluated. In the light-duty sector, the LEV I emissions standards took effect in 1994 followed by the LEV II emissions standards in 2004. Remote sensing studies and tunnel studies have characterized the exhaust from vehicles subject to these emissions standards over time, but a new study is needed to continue extending the historical record, especially as vehicles older than the LEV program begin to exit the fleet in significant numbers.

PROPOSED PROJECTS

ARB proposes funding two projects to assess emissions from cars and trucks operating on California's roads. Results from these projects will improve the understanding of the emissions reductions that have occurred in response to recent ARB regulations and will also help to assess the durability of current emission control technologies.

- Measuring Real-World Emissions from the On-Road Heavy-Duty Truck Fleet
- Measuring Real-World Emissions from the On-Road Passenger Car Fleet

Measuring Real-World Emissions from the On-Road Heavy-Duty Truck Fleet

Objective: To assess the air quality benefits of ARB's heavy-duty diesel standards, on-road measurements will be performed to measure changes in particulate matter, NO_X, and other emissions resulting from fleet turnover to cleaner vehicles.

Concept: The ARB Truck and Bus Rule is leading to the introduction of exhaust aftertreatment devices to reduce particulate matter (0.01 grams per brake horsepower-hour) and NO_X (0.2 grams per brake horsepower-hour) emissions so that, by 2023, all the heavy-duty diesel engines operating on California roadways will meet the 2010 heavy-duty engine standard. These particulate matter and NO_X emissions reductions are far greater than those associated with normal fleet turnover, and on-road measurements will help assess actual emissions changes over time for the regulated pollutants, as well as for ultrafine particles, ammonia, and the NO_2/NO_X ratio.

ARB-funded studies being conducted near the Port of Oakland are demonstrating significant emission reductions occurring in the port truck fleet due to implementation of ARB's Drayage Truck Rule. The proposed research will build upon these measurement programs by measuring emissions from the broader on-road truck fleet at three stages of implementation of ARB's statewide Truck and Bus Rule: (i) mid-2013, when a significant fraction of the fleet will have diesel particulate filters; (ii) mid-2015, when pre-1994 engines are replaced with 2010 engines; and (iii) mid-2016, when pre-1996 engines are replaced with 2010 engines, and by which time a significant portion of the fleet will have 2010 engines.

The proposed study will complement an ARB funded heavy-duty truck study that will begin simultaneously in the Los Angeles basin to perform on-road measurements in 2013, 2015, and 2017. The proposed research will measure emissions in Northern California at the Caldecott tunnel, where an uphill grade will ensure that the trucks operating under load have elevated exhaust temperatures to make aftertreatment systems functional (i.e., urea injection is active). In each of the three sampling campaigns, measurements will be performed to quantify pollutant emission rates individually from at least 1000 trucks. The measurements include nitric oxide, nitrogen dioxide, ammonia, nitrous oxide, isocyanic acid, carbon monoxide, and particle mass and size distribution. The results of this study will be used quantify the benefits of the Truck and Bus Rule over time.

Proposed level of funding: $450,000

Measuring Real-World Emissions from the On-Road Passenger Car Fleet

Objective: Measurements of vehicle exhaust made by remote sensing devices deployed at roadsides have proven very successful at showing that motor vehicle emissions in California have been steadily decreasing in response to ARB regulations. This proposed study will monitor emission trends by vehicle model and age in the light-duty on-road fleet, and explore measurement of running loss evaporative emissions.

Concept: Remote sensing device data will allow characterization of the relative importance of high-emitters to fleet average emissions, and will help evaluate the effectiveness of the LEV II program in maintaining low emissions from vehicles throughout their useful life. Remote sensing studies conducted in California since 1999 have shown a steady reduction in tailpipe emissions of hydrocarbons, carbon monoxide, and NO_X from the light-duty on-road fleet.

The proposed study will extend the measurement record to 2015. Previous studies at the on-ramp from La Brea Boulevard to Interstate 10 in Los Angeles began in 1999 and were repeated about every two years until 2005. In 2008, technology was added to include measurements of ammonia, nitrogen dioxide, and sulfur dioxide emissions. The proposed research will continue to measure emissions from vehicles at the La Brea Boulevard on-ramp location in the spring of 2013 and 2015, thereby extending the record collected since 1999, and helping establish trends for ammonia and nitrogen dioxide emissions from 2008 onward.

The project will also explore the potential of remote sensing devices for measurement of on-road evaporative hydrocarbon emissions from the light-duty on-road fleet, by estimating total hydrocarbons with modified software algorithms. This project will enable ARB to continue to observe emission trends for hydrocarbons, carbon monoxide, and NO_X, and investigate trends for nitrogen dioxide and ammonia as vehicles that meet the 2004 LEV II standard replace higher emitting vehicles in the fleet.

Proposed level of funding: $75,000

NEXT STEPS

The 14 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.