2011 Annual Research Plan

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California Environmental Protection Agency

Air Resources Board

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INTRODUCTION

The Air Resources Board (ARB or Board) sponsors a comprehensive program of research addressing the causes, effects, and solutions to air pollution problems in California. The goal of the research program is to provide timely scientific and technical information to help the Board, local air districts, and others to take effective actions to meet California's air quality and climate goals. ARB's research program is a collaborative effort with other agencies and research institutions designed to leverage air pollution research funding both nationally and internationally.

This research plan reflects ongoing strategic planning discussions and intensive efforts to identify the most urgent needs of ARB. The forward-looking research plan considers an extended timeframe as it focuses on specific program goals and timelines. Key planning milestones considered in the development of the research plan are 2020, 2030, and 2050. By 2020, California is to meet its greenhouse gas reduction target and have in place advanced technology measures necessary to meet current federal air quality standards. By 2030, California will be implementing plans for updated federal air quality standards and sustainable communities strategies required by State law. The long-term planning milestone for California's climate program is 2050. While these planning horizons reflect specific State and federal air quality and climate program deadlines, California's air quality efforts include many interim program and regulatory milestones. As a result, emissions that form ozone and particulate air pollution are decreasing each year and California's greenhouse gas reduction measures are steadily phasing in.

ARB Research Plan Themes

ARB's 2011 Research Plan reflects new program needs, long-term goals, and builds upon the comprehensiveness of California's existing air quality programs. Foundational studies on the science of air pollution continue to be the primary emphasis of ARB's research program although new topic areas emerge each year. Other themes are Air Quality and Energy, Sustainable Communities, and Behavior and Technology.

- **Air Quality and Energy** – ARB coordinates with California's energy agencies on research to support air quality and clean energy efforts. Integrated air quality and energy policies are essential to meet California's air quality and climate goals.

- **Sustainable Communities** – California's Sustainable Communities and Climate Protection Act (SB 375) is designed to encourage improved land use and transportation planning in ways that reduce greenhouse gas emissions. ARB's research emphasis is to look at ways to maximize the benefits of sustainable planning including reduced air pollution, greater energy efficiency, and cost savings.

- **Behavior and Technology** – Existing research indicates that the individual decision-making process includes a variety of considerations that influence purchasing patterns, energy conservation, and travel choices. Research in this topic will help focus attention on new opportunities for individual and collective decision-making to choose technologies and adopt use patterns that reduce greenhouse gases, smog forming pollutants, and toxic air contaminants.

- **Foundational Studies: Air Pollution Science** – The core of ARB's research program is to understand the causes and solutions to California's air pollution problems. The three primary areas of emphasis are: protecting health by reducing exposure to air pollution, attaining air quality standards, and meeting greenhouse gas reduction targets.

Twenty-three projects are recommended totaling approximately $10 million, for which we intend to attain significant co-funding. Allocations for the projects recommended for funding are distributed among key research areas as follows:

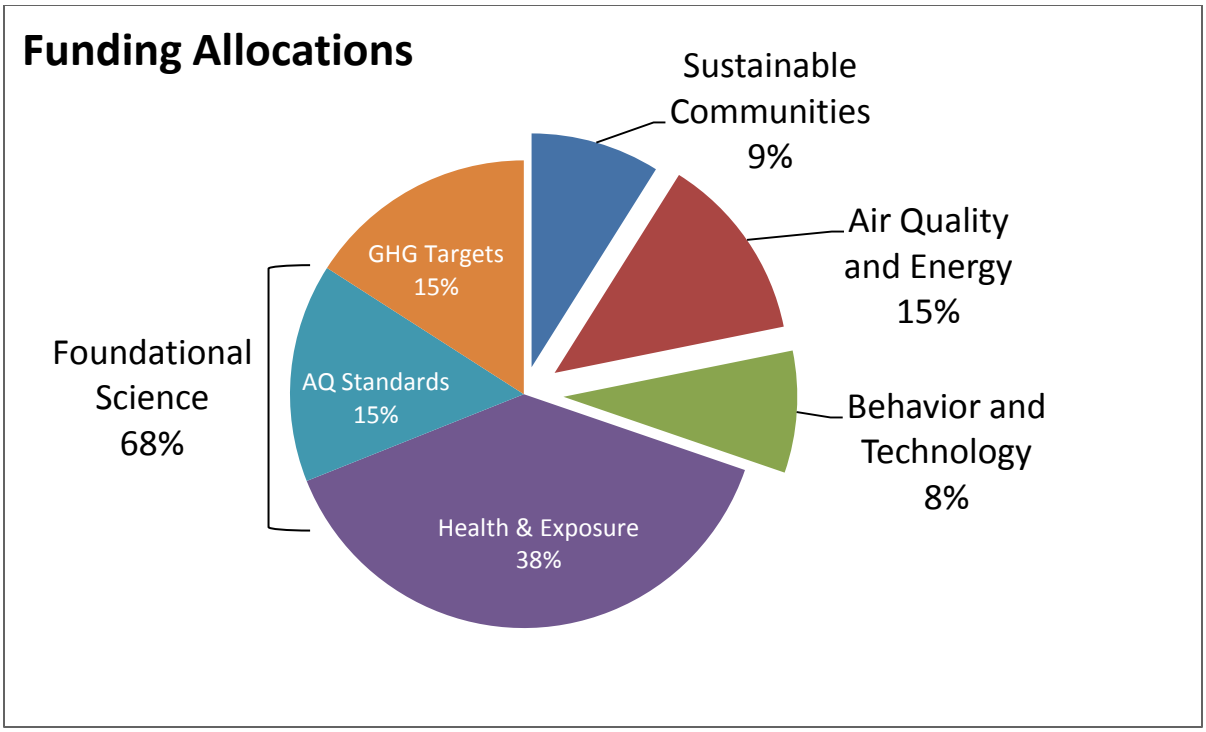


Figure 1

Planning Process

To initiate the planning process, a joint discussion was held between the Board and the Research Screening Committee to consider ARB's evolving mission and the changing context of our work. As in previous years, ARB sent out a public solicitation inviting and encouraging the public to contribute research ideas. In addition, the planning benefited from ongoing discussions with experts from multiple government agencies as well as experts from other institutions with scientific research or regulatory authority in air pollution and related fields. Based on this external input as well as internal dialogue between ARB's divisions, executive office, and the office of the chair, ARB staff prioritized specific program needs, reviewed the submitted proposals, developed additional research concepts to address gaps, and prepared an annual research plan designed to clarify important information gaps. The research concepts 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 funding approval.

Coordination, Leveraging, & Collaboration

ARB works with other California agencies to ensure that its research portfolio is non-duplicative, to identify opportunities to leverage the State's resources, and to maximize the utility of research results. To foster coordination, information is shared at all stages of the research process, including proposal review, updates on research progress, and final reports. California's Climate Action Team (CAT) has established a working group to coordinate the State's climate change research. The CAT Research Working Group maintains a database of

State-funded climate change research.[1] To complement this catalog, ARB is compiling a database of climate change research in California's public and private universities and national laboratories, in collaboration with the California Council of Science and Technology. This tool is designed to identify intellectual resources, in the form of principal investigators, ongoing or complete research, and databases, to help support California's climate program.

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 collaborations have included the California Energy Commission (CEC), National Oceanic and Atmospheric Administration (NOAA), the National Aeronautics and Space Administration (NASA), South Coast Air Quality Management District, the Coordinating Research Council (CRC), Health Effects Institute (HEI), U.S. Environmental Protection Agency (EPA), California Public Utilities Commission (CPUC), and Next 10.

History and Highlights

The Board's research program was established[2] by the Legislature in 1971 and has formed the basis of ARB's regulatory programs since its inception. ARB's research program identifies and explores questions that are critical to sound policy, including support of ambient air quality standards. Several legislative mandates have expanded and further defined the scope of the program in recent years. For example, ARB's growing research interest in climate change issues is reflected by Assembly Bill 2991 (Nuñez, 2008), which expanded membership of ARB's Research Screening Committee to include two experts on climate change.

ARB's research portfolio comprises collaborative studies involving a variety of scientific disciplines and approaches. Some of these studies are long-term and build on unique data sets, while others address specific implementation or knowledge gaps. ARB funds projects needed to design and implement effective programs to meet a broad range of statutory mandates. State law directs ARB to work with the University of California system, so where possible, ARB's research program partners with internationally recognized scientists in California.

1 http://www.climatechange.ca.gov/research/search.php
2 Health and Safety Code Sections 39700 et seq.

Over the past 40 years, ARB has carried out innovative research in areas as diverse as health effects of air pollution on vulnerable populations, complex atmospheric chemistry, and greenhouse gas emissions. Although ARB's research budget is modest, ARB's impact on the research community is greater than its limited budget size would suggest. The ARB research program delivers important research results and also provides a mechanism to influence air pollution research funded and carried out by others. Below, a few highlights from ARB's research program[3] are presented.

Children's Health Study

ARB's Children's Health Study was designed to investigate the health impacts of air pollution on California's vulnerable youth population. This study was the first of its kind, with a sample of over 5,000 children followed from 4th to 12th grade under ARB funding, and now into adulthood through the National Institute of Environmental Health Sciences.

This ambitious study has produced more than 100 peer-reviewed scientific publications that found significant, permanent reductions in lung growth from air pollution exposure and implicated air pollution in both the onset and the severity of asthma. Among the policy outcomes of this work was legislation requiring California to reassess its air quality standards to ensure the health of children, to identify toxics that pose particular hazards to children, and to assess children's exposures to pollutants at educational facilities. The study also demonstrated the health benefit of living in communities with cleaner air.

Effectiveness of NO_X Controls

In the 1950s, Dr. Arie Haagen-Smit, ARB's first chairman, revealed the source and nature of Southern California's smog through research conducted from his mobile laboratory. Haagen-Smit's pioneering work was built upon by research at the Statewide Air Pollution Research Center and the establishment of ARB's Research Program. Based on the research of Haagen-Smit and other scientists, ARB was the first agency in the world to pursue NO_X control on automobiles for ozone reduction. The efficacy of ARB's NO_X control efforts was formally recognized by the National Research Council in 1991 with its report "Rethinking the Ozone Problem in Urban and Regional Air Pollution".[4] Over the past twenty years ARB has co-sponsored research projects demonstrating the effectiveness of NO_X control in reducing PM2.5 air pollution.

3 For a more comprehensive catalog of ARB's research program, see: http://www.arb.ca.gov/research/research.htm
4 Available online: http://www.nap.edu/openbook.php?record_id=1889

Reducing High Global Warming Potential Gases

ARB's research program identified the importance and relative cost-effectiveness of reducing emissions of high global warming potential (GWP) gases. Reducing emissions from this group of greenhouse gases is an important component of California's plan to reduce emissions to 1990 levels by 2020. High-GWP gases account for approximately 15% of the state's carbon footprint and ARB's research program has identified several low-cost opportunities for substantial reductions. ARB has already put in place rules to reduce high-GWP gas emissions from commercial refrigeration and motor vehicle air conditioning systems as well as reduce sulfur hexafluoride from all applications.

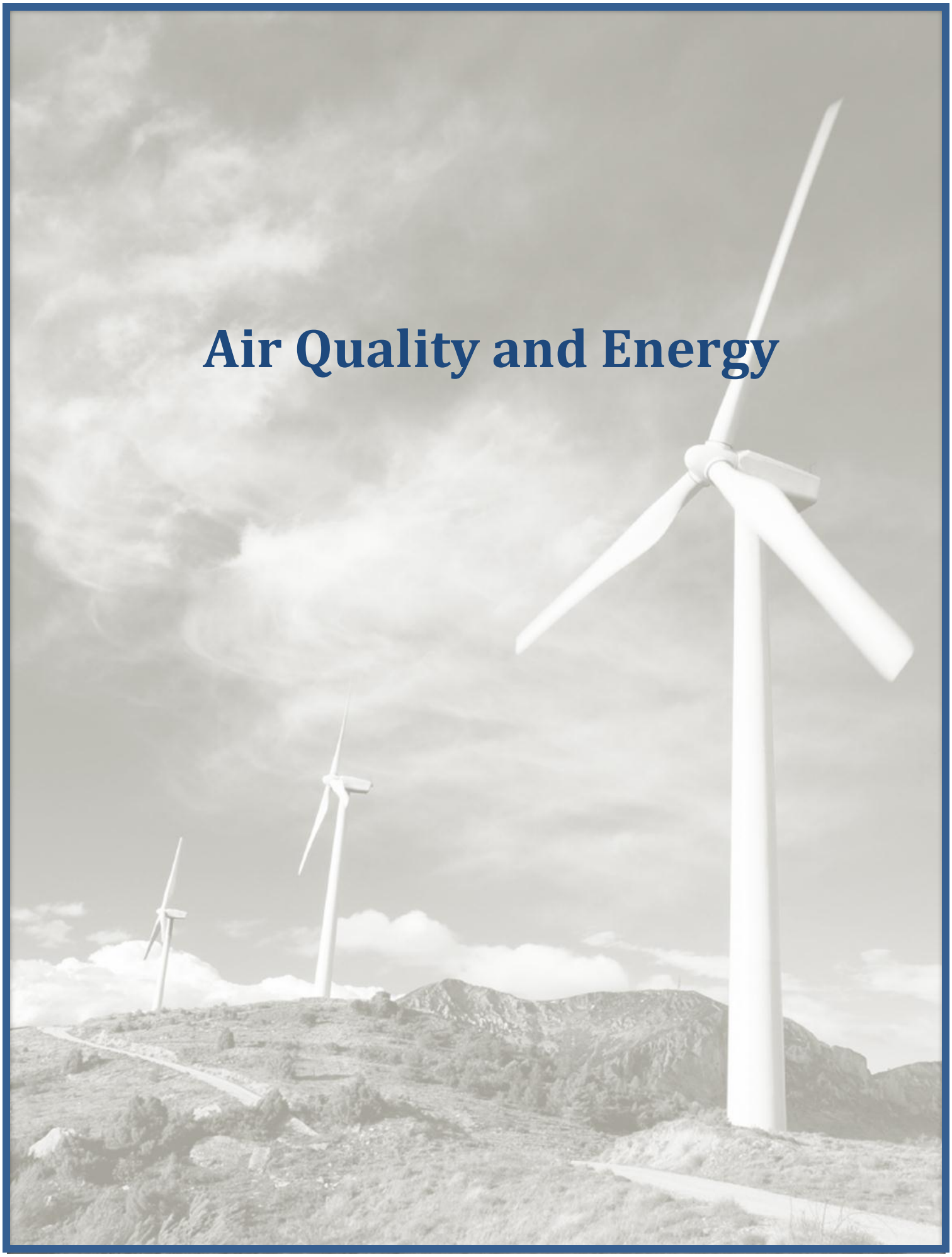
Improving Indoor Air Quality

ARB sponsored many pioneering research projects that prompted similar national studies as well as the first legislation in the nation to protect people from some of the most harmful indoor exposures. A study of formaldehyde emissions from building materials and many other products prompted ARB's regulation limiting formaldehyde emissions from compressed wood products. Recent federal legislation requiring the U. S. EPA to develop a national regulation will assure that all Americans are protected from excessive formaldehyde exposures from plywood, particleboard, and other wood-based building materials that are prevalent in modern construction. Similarly, research conducted by ARB staff on purported "air cleaners" that intentionally emit ozone prompted legislation in 2006 (AB 2276, Pavley) directing ARB to regulate ozone emissions from indoor air cleaning devices. ARB now certifies indoor air cleaners under the new regulatory program, and high ozone-emitting devices are prohibited from sale in California. Also, ARB's joint study on air quality in portable classrooms contributed to a number of state and school district policy changes that have improved health conditions in California schools.

Air Quality Field Studies

Multiple air quality field studies carried out in California collected air monitoring data, information on pollutant transport, and emissions data that answered critical questions about the nature and causes of air pollution. Information from such field studies has helped improve air quality modeling and other science assessments essential to California's implementation of the federal Clean Air Act. Most recently, CalNex 2010, a major collaboration with NOAA, is providing vital data on the composition, formation, and transport of air pollution in California. CalNex 2010 is the first California field study to look at both greenhouse gases and smog-forming pollutants. More than 40 ARB-sponsored field studies over several decades have provided data to guide the development of cost-effective control programs that have dramatically improved California's air quality. These studies have been highly leveraged, with ARB funds often matched by more than two to one.

Air Quality and Energy



AIR QUALITY AND ENERGY

ARB's research plan includes several projects that support California's goal of a clean energy future. While California has been very successful in reducing smog forming pollutants, meeting stricter clean air standards while reducing greenhouse gases will require well integrated energy and air quality programs. There are several categories of ARB research encompassed within in the theme of clean energy and air quality. The transportation category includes new vehicle technologies, cleaner fuels, and supporting infrastructure. Renewable energy is another category that will reduce both greenhouse gases and smog forming pollutants. Energy efficiency is a third broad research area with direct benefits to greenhouse gas and air pollutant reduction efforts.

ARB works closely with the California Energy Commission (CEC) and California Public Utilities Commission (CPUC) to align policies and plans for meeting common energy and air quality goals. With the enactment of California's Global Warming Solutions Act, the areas of interagency program collaboration have increased. As California implements cleaner transportation technologies and fuels, new renewable electricity standards, and enhanced energy efficiency programs, coordinated energy and air quality policies are more important than ever. CEC's Public Interest Energy Research (PIER) program is funding transformational demonstrations that emphasize an integrated suite of advanced energy efficiency, renewable energy, and other technologies. ARB research efforts in this arena are designed to complement those of the energy agencies by focusing on the air quality co-benefits of clean energy and improved energy efficiency.

California's long term goal is an 80% reduction in greenhouse gas emissions by 2050 relative to 1990, which will require a comprehensive transition to clean energy. Achieving the new reductions in smog forming pollutants needed by 2020 to meet federal air quality standards will also depend on cleaner energy sources and improved energy efficiency. Long lead times are involved in developing new technologies, infrastructure, and changes in policy, planning, and permitting. Important capital investments will be made over the coming decades, so recognizing the linkage of air quality and energy policies is essential to the success of our programs.

ARB staff solicited research ideas from the academic community, consulted with internal and external experts, and considered what research is currently being funded by other national, state, and local agencies, especially the CEC PIER Program. The four research projects in this plan are focused on ARB needs that complement research efforts by other agencies. Each project has been reviewed by energy agency staff and will be coordinated with their research program in all phases of project development and implementation.

The first project focuses on the air quality co-benefits of clean energy, building on assessments funded by the CEC PIER program. The next project supports clean transportation infrastructure by collecting truck travel data critical for developing goods movement and air quality policy.

The third project focuses on renewable biofuels. The final project addresses the need for consistent tools for life-cycle analysis of transportation fuels and consumer goods and services.

Air Quality Co-Benefits from California's Clean Energy Future

Objective: Transitioning to cleaner energy sources is a core strategy for complying with existing federal air quality deadlines by 2023 and meeting an 80% greenhouse gas emission reduction target by 2050. The objective of this research is to identify the air quality co-benefits of clean energy strategies that reduce greenhouse gas emissions. The research will build on previous and ongoing clean technology assessments.

Concept: Meeting the 2050 target will require innovations beyond what is currently available and affordable. Several portfolios of energy options are being actively explored to offer critical flexibility and spur innovation, given the uncertainty regarding which mix of technologies will prove economically, socially, legally, and logistically viable. In its recent report "California's Clean Energy Future: The Path to 2050", the California Council on Science and Technology concluded that California can achieve a 60% reduction with technologies currently deployed at scale now or demonstrated, emphasizing building efficiency, electrification of the transportation sector, and decarbonization of electricity and fuels. However, their analysis optimistically assumed large-scale deployment of new nuclear plants and carbon capture and storage of CO_2 from coal- and gas-fired utilities and industrial facilities. A more detailed technology assessment for CEC-PIER, led by Lawrence Berkeley National Laboratory, University of California at Berkeley and the University of California at Davis, reached similar conclusions, but with greater emphasis on renewable energy sources. Although traditional air pollutants and greenhouse gases have common sources, both of these assessments focused only on greenhouse gases.

The air quality co-benefits of these clean energy technologies will be assessed. Conversely, ozone and some PM2.5 components (e.g., black carbon) exert a climate impact and these interactions will also be considered. The International Institute for Applied Systems Analysis in Austria has developed integrated assessment models for Europe, Asia, and several countries to identify portfolios of measures that improve air quality and reduce greenhouse gas emissions at least cost. The capabilities of the GAINS (Greenhouse gas – Air pollution Interactions and Synergies) model will be considered for California. The project will also be coordinated with a complementary PIER-funded project using the SWITCH model to assess how the electricity system in the Western U.S. would evolve under different CO_2 policy constraints by simulating renewable sources of energy and potential changes in the seasonal/diurnal profile of electricity demand, and another studying other environmental issues associated with the energy scenarios (e.g., water consumption for biofuels).

Proposed level of funding: $300,000 - $500,000

Improved Characterization of Truck Travel within California's Goods Movement System

Objective: An improved understanding of truck characteristics is needed to develop robust statewide and regional goods movement models for California. The objective of this research is to develop and implement an improved data collection methodology for trucks traveling on the state's highways with the goal of better understanding how characteristics such as truck type, weight, body type, and usage affect emissions.

Concept: The proposed study is part of a broader effort by ARB to develop an improved understanding of freight related emissions in California. ARB is currently funding two other studies with the University of California at Irvine to develop a traffic database and tools to convert measurements from existing roadway sensors into roadway-specific and regional estimates of total VMT, truck flow and speed. However, even with these enhancements, this traffic database does not provide information on truck body classification and the relationship between body size and weight as well as other characteristics influencing emissions from the truck fleet on California's highways.

The proposed research will develop a new methodology for classifying trucks, test its effectiveness through a proof-of-concept deployment at an existing truck scale, and then retrofit a much larger number of traffic detectors. University of California at Irvine will then use the resulting data to update their existing truck traffic model to include truck weight, class (axle) and body type data from which information about seasonality, empty truck movements, and potentially even commodity type movements may be derived.

This project will build upon other goods movement related studies recently completed by the Federal Highway Administration (FHWA), the California Department of Transportation (Caltrans), and the ARB, including development of a first generation California-specific freight model, an analysis of existing goods movement data and data gaps, new databases to support goods movement model development and calibration, and a broader and more comprehensive second generation freight modeling system for California.
Proposed level of funding: $350,000

Assessment of the Emissions and Energy Impacts of Biomass Use in California

Objective: The objective of this research is to assess the emissions and energy balance from waste-to-energy applications and to analyze local infrastructure, integrating distribution and transmission of biogas within the natural gas system. Determining the emissions and energy impacts of waste-derived biogas across a broad range of potential sources will inform both air quality and energy agencies in California.

Concept: Biomass has the potential to provide a significant portion of the energy requirements in California while also addressing air quality and waste disposal issues. While most biomass energy is derived from wood and forest residue, there is a growing trend toward use of municipal solid waste and wastewater refuse to generate electricity and renewable fuels. Biogas from waste has the potential to provide added net energy benefits, because the

feedstock is already available. Anaerobic digestion of organic waste in landfills and wastewater treatment plants also generates biogas, which contains high methane concentrations. A large portion of biogas is still vented, which contributes to nearly 2% of the total greenhouse gas emissions in the U.S. However, this biogas can be utilized as a substitute for natural gas after some compounds are removed from the biogas stream. Using the biogas in any natural gas driven energy conversion device reduces the need for conventional fuel, contributing to energy sustainability while reducing greenhouse gas emissions. Apart from reductions of greenhouse gas emissions and improvements in energy sustainability, biogas use could help reduce criteria pollutant emissions. This is because biogas can be used in stationary fuel cells to produce electricity and hydrogen, which can then be used as a transportation fuel for electric and hydrogen fuel cell vehicles. These vehicle technologies could reduce emissions of nitrogen oxides (NO_X) and particulate matter compared to combustion-based vehicles using gasoline or diesel fuels. Advanced stationary source technologies for distributed generation applications are being developed. ARB funds a low-NO_X dairy manure digester in the San Joaquin Valley while the CEC PIER Program funds an advanced engine technology in the Sacramento Valley that can achieve extremely low levels of NO_X without aftertreatment catalytic converters.

A thorough evaluation of the potential and constraints of neutral carbon electricity and vehicle fuel (i.e., hydrogen and/or biogas) supply will be conducted based on the regional renewable bio-resources in California, but primarily in the South Coast Air Basin and the San Joaquin Valley. These areas include diverse sources for potential biomass based energy such as waste water treatment facilities, landfills, green waste from urban areas, and agricultural and dairy waste. This will include a determination of the impact of implementation of the CEC 2011 Bioenergy Action Plan, including criteria pollutant emissions, such as NO_X.

The CEC has established the California Biomass Collaborative to enhance the sustainable management and development of biomass in California for the production of renewable energy, biofuels, and products. This research proposal will be developed with CEC and the Collaborative to complement their research program, and to utilize findings from its recent and ongoing studies. The results of this research will quantify the available bio-fuel sources and estimate the potential corresponding hydrogen and biogas generation capacity. A full characterization of waste-to-energy applications will provide a scientific basis to support technology options for implementation of ARB's Low Carbon Fuel Standard. The project will be coordinated with CEC PIER and the Biomass Collaborative for a comprehensive assessment of the economics and optimal use of biomass for achieving California's clean energy future.
Proposed level of funding: $150,000

Improving Life-Cycle Assessment Tools for Carbon Accounting

Objective: Improving the available information on embedded carbon in products manufactured, purchased, consumed, or disposed of in California can help influence purchasing decisions in ways that reduce greenhouse gas emissions. The life-cycle analysis (LCA) tools used to calculate these embedded emissions are uncertain and need to be improved. This research will systematically compare commonly used LCA tools, explore the underlying data and assumptions to understand any major differences, and identify and address the barriers to

conducting life-cycle assessments, for example the need for simple-to-use, publicly available tools and procedures.

Concept: While several efforts to address embedded emissions are underway, the variety of LCA tools commonly used have never been systematically compared and reconciled. There is also a need to understand the tradeoffs of using LCA as a policy tool and to provide practical recommendations for the use of LCA. California's Low Carbon Fuel Standard considers the embedded carbon in transport fuels from direct production and indirect land use change, rather than just tailpipe emissions. In addition, several efforts to address embedded emissions in consumer products are underway in California and elsewhere. The CoolCalifornia.org calculator for household carbon footprints includes life-cycle emissions for foods, goods, and services. California's Department of Toxic Substances Control is developing a "Green Chemistry Initiative", which will consider life-cycle emissions (including GHG) to reduce the environmental and public health impact of consumer products sold in California and require the consideration of less toxic alternatives. Life-cycle inventory standards for consumer products are emerging from the United Kingdom Carbon Trust and the World Resources Institute/World Business Council for Sustainable Development.

In California, ARB and the CEC have been the primary funders of relevant research, and the U.S. EPA, the National Renewable Energy Lab, and private foundations and corporations have funded numerous other studies. The first step will be to conduct a joint workshop with the Coordinating Research Council at Argonne National Laboratory to identify existing development and comparison studies for biofuels, catalog ongoing work, and develop research recommendations and the level of interest in jointly funded efforts. If possible, this project should also examine environmental impacts beyond GHG emissions (e.g., energy, water, toxic air contaminants and VOCs) and rebound effects. The results of this research will enable more consistent life-cycle analyses and could be used to identify significant sources of embedded carbon for possible reduction.
Proposed level of funding: $300,000 - $500,000

Sustainable Communities

SUSTAINABLE COMMUNITIES

The Sustainable Communities and Climate Protection Act of 2008 (Senate Bill 375) directs California's metropolitan planning organizations to develop sustainable communities strategies that meet a regional greenhouse gas reduction target through integrated land use, housing and transportation planning. Development of these sustainable communities strategies also provides an opportunity for associated emission reductions that will be needed to attain air quality standards for ozone and particulate matter.

Since the passage of SB 375, ARB staff have been working closely with other state agencies, regional planning organizations, and local air quality agencies to develop methodologies, tools, and resources to support development of sustainable communities strategies. This includes assessing the current literature and identifying areas where additional research may be needed such that available resources are used wisely. A significant amount of research on sustainable communities is currently underway at the federal, state, and local levels although there are a number of areas where more work is needed.

For example, the Partnership for Sustainable Communities, a federal interagency partnership formed in 2009 between the U.S. Environmental Protection Agency, the Department of Housing and Urban Development, and the Department of Transportation, has dedicated more than $2.5 billion to help develop sustainable communities nationwide, including funding relevant research. In September 2010, Virginia Tech's Metropolitan Institute and Center for Housing Research brought together more than 50 national experts to identify top research priorities that would help the Partnership promote more sustainable communities.[5] In the area of green and energy efficient affordable housing research, the experts suggested future research include assessing the co-benefits of energy efficiency improvements, the impact of education and real-time metering on energy savings, and how to maximize the use of energy efficient mortgages and other financing mechanisms for residential energy improvements.

In California, ARB-funded studies are currently underway to assess the role of land use planning in reducing residential energy consumption and to quantify the effect of local government actions on reducing vehicle miles traveled. Other state agencies including the California Energy Commission (CEC), the Governor's Office of Planning and Research (OPR) and the California Department of Transportation (Caltrans) are also funding research on sustainable communities. For example, through their Public Interest Energy Research (PIER) Program, the CEC is funding a team of researchers from UCLA, UC Berkeley, and UC Davis to develop methods and tools to estimate community-scale energy usage and its relationship to socio-economic factors. The PIER Program has also committed $4 million through the UCLA Institute of the Environment and Sustainability to establish the California Center for Sustainable Communities Research (CCSCR) that will serve as a clearinghouse for the synthesis, coordination, and communication of

5 Dawkins, C., Schilling, J., and Alfonzo, M., Policy Research Priorities for Sustainable Communities, Research Roundtable Final Report, The Metropolitan Institute and the Virginia Center for Housing Policy, Virginia Polytechnic Institute and State University, February 25, 2011.

research related to sustainable energy systems. Much of the focus of the CCSCR will be in helping California meet the goals of SB 375 and AB 32.

The Center for Resource Efficient Communities (CREC) at the University of California at Berkeley has recently released several white papers exploring the links between community design and energy efficiency and providing recommendations for future research on both technical issues, such as thermal comfort analyses, and socio-economic issues, such as permitting and financing processes. Three key research gaps identified by CREC are assessing street design and travel behavior, identifying cool community strategies, and creating new building codes, standards, and visions for more resource efficient communities.[6]

In developing the four research concepts under the topic of sustainable communities, ARB staff considered the research priorities identified by Virginia Tech, the University of California at Berkeley, and other experts as well the research currently being funded by other national, state, and local agencies such as the California Energy Commission. The four research concepts recommended for funding in this plan are: assessing the economic benefits and costs associated with smart growth strategies, quantifying the greenhouse gas co-benefits of energy efficiency improvements in buildings, determining the extent to which complete street conversions encourage increased walking and cycling, and a pilot program to implement and assess improvements to financing programs for existing building retrofits. As ARB staff further develop these research proposals, they will coordinate with their counterparts in other agencies in pursuing co-funding opportunities through collaborations such as the newly established CCSCR.

Analyzing the Economics of Smart Growth Strategies

Objective: This research would provide information to assist local and regional governments in developing sustainable communities strategies under SB 375. The goal for this project is to identify and quantify economic benefits and costs associated with specific smart growth strategies, including impacts on local governments, communities, and individuals.

Concept: Smart growth is an urban planning and transportation concept focused on compact community designs with transit-oriented, walkable, bicycle-friendly land use, including neighborhood schools, complete streets, and mixed-use development with a range of housing choices. Local government officials making land use and transportation planning decisions must balance multiple goals and economic considerations. Although research has been conducted on various aspects of smart growth, including economic impacts, there is a need for a comprehensive assessment, especially related to strategies suitable for California.

The first task is to identify and summarize, through literature review and expert consultation, which facets of smart growth have important economic impacts as well as any studies that have already been completed in this area. Factors to be considered range from the regional scale

6 Eisenstein, W., Building Energy Efficient Communities: A Research Agenda for California, Center for Resource Efficient Communities, UC-Berkeley College of Environmental Design, March 31, 2010.

such as the transportation infrastructure system and labor productivity to the individual scale including housing, transportation and utility costs, medical expenses, health, and livability. The second task will be to quantify the economic benefits and costs of these different factors, especially as they apply to California. This may be done through a combination of surveys, empirical data collection, and modeling assessments. The third task will be to develop robust quantitative results illustrating the potential economic benefits and costs of implementing smart growth policies.
Proposed level of funding: $300,000

Quantifying the Comprehensive Greenhouse Gas Co-Benefits of Green Buildings

Objective: As California moves towards better quantifying greenhouse gas emissions reductions associated with energy efficiency improvements in buildings, research is needed to fully account for the reductions associated with related improvements in the water, waste, and transportation components of building projects. The objective of this research is to expand existing building energy use forecasts and surveys to include non-energy features such that they capture the comprehensive range of energy and greenhouse gas emission benefits associated with all building related improvements.

Concept: Green buildings are not just energy efficient buildings; they are designed, built, operated and maintained to reduce water consumption, solid waste, and transportation-related impacts. These ancillary greenhouse benefits are not typically reflected in the current greenhouse gas emissions reductions estimates for the building sector. There is a statewide energy forecast and a number of existing building surveys utilized to measure energy usage in commercial and residential buildings. The California Energy Demand Forecast published by the California Energy Commission (CEC) provides a baseline of energy consumption by end use for the commercial sector. The Residential Energy Consumption Survey (RECS) is a comprehensive source of national-level data on energy-related information for U.S. households. Additionally, there is a 2009 Residential Appliance Saturation Survey (RASS), administered by the CEC that includes a dataset of energy end use, building characteristics, and appliance usage in 25,000 households across California. The CEC also develops an energy budget to assess compliance of new buildings with the Title 24 Energy Code.

The investigators will examine the energy demand forecast, existing end use surveys, and the energy budget to identify opportunities to expand them to include non-energy features such as water usage, waste generated, and transportation patterns. As part of this research project, investigators will develop a comprehensive end use survey or census of California green buildings. The Green Building Information Gateway (GBIG) Explorer is a beta version online tool that summarizes information on green buildings throughout the United States and includes metrics, maps, and project profiles for LEED certified projects nationwide. The investigators will use GBIG Explorer as a starting point to develop a building census of green buildings in California. The census will be used to quantify the GHG emission reductions of the water, waste, and transportation related components of green buildings. An analysis of additional co-benefits such as a reduction in criteria pollutants will also be completed to compare green buildings to standard buildings. The results of the study are intended to provide current

information and also be used in the future for ongoing assessments of air quality and other environmental benefits of green buildings.
Proposed level of funding: $200,000

Determining the Benefits of Complete Streets Conversions

Objective: The use and development of complete streets is largely motivated by potential benefits, such as decreased vehicle miles traveled (VMT), improved safety, reduced transportation costs, and enhanced active travel. The objective of this research is to determine the impact of complete street designs on usage of different modes of transportation and to quantify the extent to which specific components of street conversions (e.g. tree planting) contribute to increased walking and cycling.

Concept: A complete street is a roadway designed to enable all types of transportation, including walking and cycling, as well as using private motor vehicles and public transportation. The benefits of complete streets are reduction in VMT and improved public health by active transport (walking and cycling). While the health benefits of increased active transport are well known, the potential usefulness of complete streets in promoting active transport is not as well studied. This study will be designed around natural experiments, in that data will be collected both before and after the conversion of existing corridors to complete streets. The study will examine five or six streets, which will be carefully selected to assure the ability to be able to gather data both before and after the conversion to a complete street. Data will be collected on the changes in cycling and walking, as well as any changes in traffic volume, speeds, vehicle type and characteristics, and other relevant information. In addition, specific attributes of the street conversions (e.g. tree planting, thermal conditions) will be documented and their impacts on transportation mode choice assessed.

The results of this study will help to determine the effectiveness of the complete street conversion and the potential reduction in VMT. This project will also generate information that can be used in the future to help assess personal exposure of motorists, bus riders, bicyclists and pedestrians to air pollutants associated with traffic, especially ultrafine particles and PM2.5, which will provide guidance on how to promote the known benefits of active transport. The results from this project will help the ARB in providing information to urban planners on complete street designs that encourage the usage of active and public transportation.
Proposed level of funding: $200,000

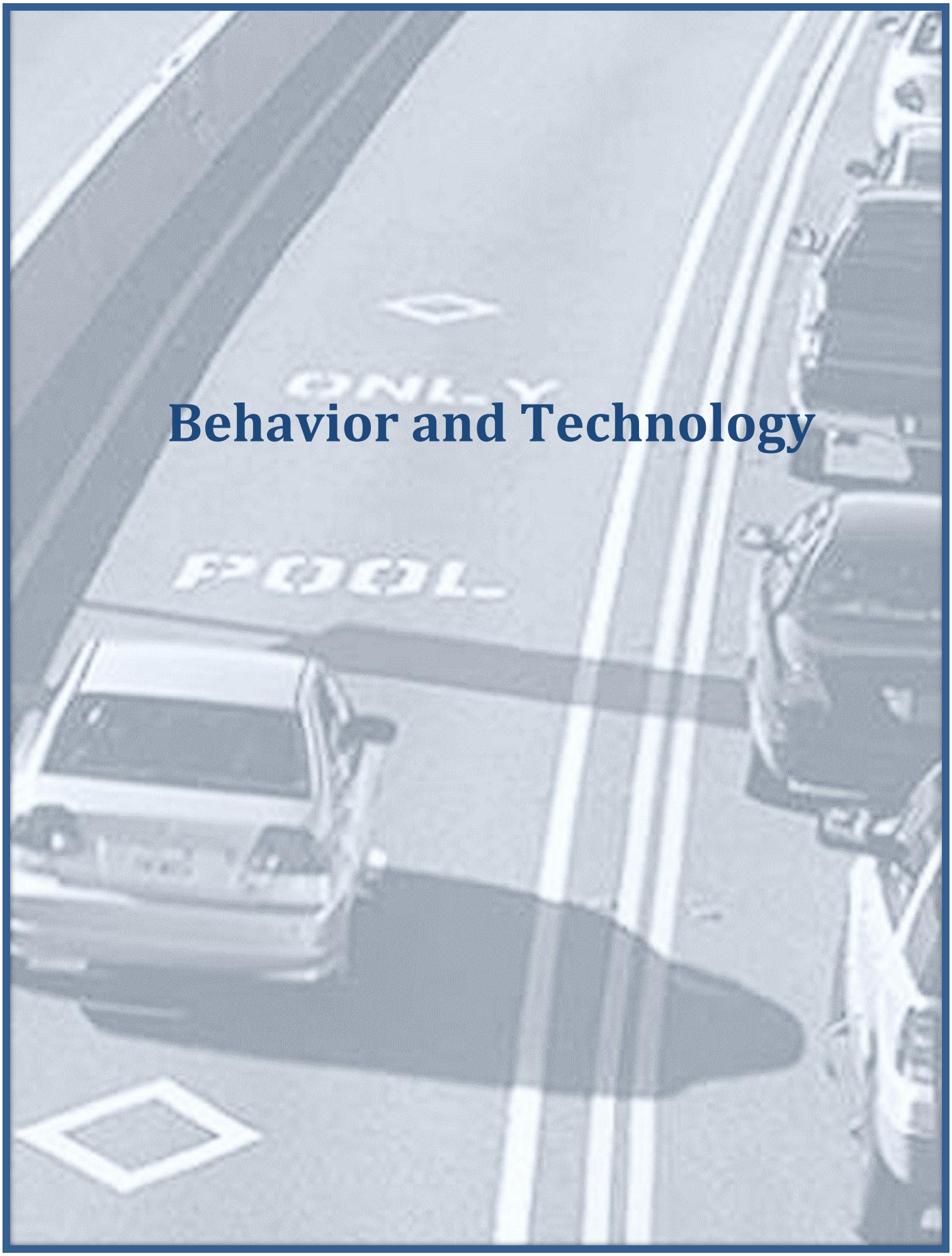
Pilot Program to Assess Improvements to Financing Programs for Building Retrofits

Objective: The goal of this project is to conduct a pilot program to test the effectiveness of potential improvements to financing programs for energy efficiency retrofits to existing homes and commercial buildings. The study is designed to demonstrate ways to increase participation in financing programs and expand the number of energy efficiency building retrofits in California.

Concept: Achieving California's goals to reduce greenhouse gas emissions from the building sector will require a substantial investment in retrofitting the existing building stock. A recent study funded by the California Public Utility Commission (PUC) determined that an annual investment of $4 billion per year is needed to achieve California's energy efficiency goals.[7] Current levels of investment appear to be only half that amount. Additionally, the rate at which building owners are taking advantage of the available financing programs is lower than expected. As a result, both an increase in capital and an increase in the usage of existing funding programs are needed to achieve California's building retrofit goals. This study will expand on the recent analysis completed by PUC consultants to assess the key finance programs available for the single family residential and commercial building sectors. The research team will work with federal and state initiatives to reduce the interest rates on key finance products available for single family homeowners. The research team would work with energy services/performance contracting (ESCo) providers, debt financing lenders, and the leasing industry to implement changes to the financing options available for the commercial building sector. A pilot study would be completed to test the recommended changes, gather data, and validate the revised approach to improve residential and commercial building financing programs and assess whether and at what cost the changes can be implemented on a larger scale.

Proposed level of funding: $200,000

7 Harcourt Brown & Carey, Inc., Energy Efficiency Financing in California, Needs and Gaps, Preliminary Assessment and Recommendations, Presented to the California Public Utilities Commission, July 8, 2011.



Behavior and Technology

BEHAVIOR AND TECHNOLOGY

Many Californians are making green purchasing decisions, conserving energy at home and at work, and re-thinking their transportation choices to favor options that not only save fuel, but save time and promote health. Current literature indicates a real potential to improve air quality and reduce greenhouse gas emissions through programs that effectively promote environmentally-friendly decisions. However, opportunities are often missed because programs are designed or implemented without accounting for the complexities of human behavior. Research in the fields of behavioral economics, sociology, psychology and neurology has shown that consumers frequently behave in a manner that defies traditional models of rational economic choice. Proven energy-saving technologies that are sound economic investments, for instance, are often adopted at rates that are significantly lower than might be predicted by simple economic models. Conversely, some Californians put solar panels on their house or purchase fuel-efficient vehicles, even if there are more cost-effective strategies to reduce greenhouse gas emissions, in part because these solar panels and hybrid vehicles are very visible indicators of their concern for the environment.[8] Thus, there is also room to encourage "clean" choices through non-economic motivations, such as those that appeal to social norms.

ARB and its partners at UC Berkeley and Next 10 have developed the CoolCalifornia.org web resource to provide free, easy-to-use tools and resources to all Californians with the goal of facilitating voluntary carbon footprint reductions. In support of this effort, ARB has sponsored a variety of research projects, including developing academically rigorous, user-friendly household and small business carbon footprint calculators, and additional research to support the development of local government climate action planning. ARB is also working with the Natural Resources Agency to develop a "funding wizard" for CoolCalifornia.org (currently available as a prototype[9]) which will allow California households, small businesses, local governments, and schools to search for funding to support their carbon footprint reduction projects. And finally, ARB has funded a pilot competition within and among California cities that will incorporate the CoolCalifornia.org household carbon footprint calculator and will test the effectiveness of various types of information delivery and social motivation on carbon footprint results.

To further strengthen and broaden ARB's efforts, research is needed to develop and test non-economic explanations for observed technology choice and use patterns. Research is also needed to understand both economic and non-economic motivations for "clean" or more environmentally-friendly technology choice. Standard economic interventions attempt to close the gap through pricing or information strategies, but these strategies prove ineffective if behavioral factors related to technology adoption and use are not addressed. Several successful efforts to encourage residents to reduce air pollution and greenhouse gas emissions through appealing to social incentives and accounting for behavioral barriers have already been

8 Griskevicius, V., Tybur, J.J., Van den Bergh, B. Going Green to Be Seen: Status, Reputation, and Conspicuous Conservation. Journal of Personality and Social Psychology, 2010, Vol. 98, No. 3, 392–404
9 www.coolcalifornia.org/funding-wizard-home

documented, with quantified reductions in carbon footprints, energy use, electricity, and water consumption ranging from 5 percent to 20 percent.[10] Understanding the nature of consumer choices and decision making can provide critical information for developing policies and programs as California transitions to an energy-efficient and low carbon economy.

The transportation and built environment sectors are of particular interest to ARB since a significant amount of air pollutant and greenhouse gas emissions are heavily influenced by individual actions. To support ARB's mission over the coming decades, research in this area will focus on real-life decision-making in these sectors. Results will improve understanding of behaviors that either prevent regulatory programs from achieving expected results or could significantly expand the effectiveness of programs. Results will also identify potentially replicable strategies to further encourage voluntary emissions reductions.

The Built Environment

Recent studies affirm that behavioral change has the potential to reduce energy consumption in buildings by 20-40 percent.[11] However, substantial reductions of energy consumption in buildings will only be achieved if Californians reduce their plug load, purchase more efficient appliances and products, and generally use less energy. All of these factors will require changes in individuals' habits and purchasing behavior.

Various State and Federal government agencies have funded or currently are funding recent, relevant research and analyses related to building energy use behavior, including the California Public Utilities Commission, the Energy Commission (through their PIER program), and the U.S. Department of Energy (through ARPA-E). One key resource that has been developed as a result of the Department of Energy and Energy Commission PIER research is Lawrence Berkeley National Lab's web-based Home Energy Saver tool, which allows households to "benchmark" their energy consumption relative to a database of similar households, and to identify actions that are likely to help them reduce their household energy use.[12] ARB also has several research contracts underway to explore energy use behavior in residential and commercial buildings as well as social and behavioral barriers and motivations that influence building energy use. Questions currently being addressed under ARB sponsored projects include:

- What factors play into energy consumption in residential and commercial buildings?
- How do residential consumers respond to information about electricity consumption?
- How do commercial building operators, managers, and occupants respond to advanced visualization of building energy use?
- How do people respond to social incentives regarding electricity consumption?

Results from these on-going studies will address the persistent gap between potential and actual energy use and support the Board's efforts in fostering voluntary conservation and GHG

10 Cool Mass Energy Smackdown

11 e.g., Dietz et al., 2009, Gardner and Stern, 2008, Laitner et al., 2009

12 Home Energy Saver functionality will be incorporated into the CoolCalifornia.org carbon calculator by the end of 2011.

emissions reductions. Since several projects are currently underway, no projects will be funded during the 2011-2012 fiscal year in this area.

The Nexus of Transportation and Behavior

The 2050 Vision, prepared in response to the State Alternative Fuels Plan (AB 1007, Pavley, 2005), suggests a future in which Californians spend less time driving fewer miles per year on a per capita basis and choose vehicles (or non-vehicular modes of transit) that are more fuel-efficient and/or rely on lower-carbon fuel sources. These goals are further supported by SB 375 (Steinberg, 2008) which is expected to reduce vehicle miles traveled (VMT) by improving land use and transportation system design, and AB 118 (Nuñez, 2007), which directs State agencies to develop the Alternative and Renewable Fuel and Vehicle Technology Program.

Relatively little published research has addressed transportation behavior in California. The California Energy Commission's PIER Program has supported much of what has been done on transportation behaviors in California, and ARB has co-funded several research projects. At the UC Davis Institute of Transportation Studies, which is widely recognized for its efforts in this area, researchers are working on a variety of transportation behavior projects[13] that include:

- Plug-in Hybrid Electric Vehicle (PHEV) consumer studies (ARB co-funded)
- Consumer response to vehicle instrumentation
- Vehicle choice
- Eco-driving

Several critical research gaps remain pertaining to effective promotion of environmentally-friendly transportation choices. ARB sponsored research will target specific gaps of particular significance to California, building upon related work and seeking opportunities for co-funding with other agencies and funding sources. The following three transportation-related projects will be funded in the 2011-2012 fiscal year.

Modeling Household Vehicle and Transportation Choice and Usage

Objective: The objective of this research is to develop a model of household vehicle and transportation choice and usage that will allow more rigorous evaluation of policies intended to reduce transportation emissions and to inform sustainable community planning. Identifying the geographic and demographic characteristics of households with very low transportation emissions (especially those with low VMT) and gaining a deeper understanding of the factors that shape their transportation footprints can help inform the development of sustainable communities strategies under SB 375.

Concept: ARB has previously sponsored research related to forecasting new vehicle purchases, but this model (CARBITS) has focused exclusively on the vehicle purchase decision without regard to expected vehicle usage or market factors (beyond fuel prices), and does not account for consumer acceptance of advanced vehicles. Previous research into the factors which influence ridership of public transit and use of other alternate transport modes should be

13 http://www.its.ucdavis.edu/people/faculty/turrentine/index.php

incorporated into an improved model. Related work funded by the California Energy Commission, as well as the California Household Travel Survey (and an Energy Commission-funded expansion of this survey), could be leveraged for this research. The investigators will develop a joint vehicle choice and usage model for light-duty vehicles (including zero emission vehicles specific to California's fleet) that more accurately captures how transportation-related choices and market effects influence emissions. This should include a better understanding of households that choose to have low or zero VMT, consumer acceptance of emerging low-emission vehicles, and considerations that affect vehicle purchase choice, such as anticipated or actual vehicle use and market factors (beyond fuel price).

The model will link household vehicle and transportation choices to demographic information that identifies the characteristics of households that have very low transportation emissions and/or VMT. Researchers will investigate what individual-level factors are associated with low-emission transportation behavior, as well as delineate behaviors that typify low-emission transportation choices for various socioeconomic groups. The relative importance of barriers to low-emissions travel, as well as potential leverage points for mitigating these barriers, will be explored. This research will also provide ARB with more realistic projections of future vehicle sales for emissions modeling purposes. The results of this work will be used to evaluate policies intended to promote acceptance of low-emission transportation modes, identify potential incentives to reduce vehicle miles traveled at the household level, help policy-makers understand the barriers to adoption of low emission and sustainable forms of transportation, and help constrain future transportation emissions.
Proposed funding: $300,000

Understanding the Potential Benefits of Interactive Transportation Technologies

Objective: The objective of this research is to identify the potential for in-vehicle feedback systems to reduce transportation-related emissions through changes in driving behavior.

Concept: In-vehicle feedback systems (such as on-board, real-time fuel efficiency display technologies) are available but have only penetrated select, atypical niches of the market place. Providing drivers with appropriate in-vehicle feedback may foster a broader awareness of eco-driving, and encourage not only better fuel economy but possibly also a reduction in vehicle miles traveled (VMT). Observations of impacts associated with the limited penetration of in-vehicle feedback technologies suggest that they may offer a viable, low-cost approach for voluntary greenhouse gas emissions reductions from personal vehicles. Ongoing and recently funded work at UC Davis, UC Riverside and Eaton Corporation should be leveraged and/or expanded upon in this research. The California Household Travel Survey, and a California Energy Commission-funded expansion of this Survey, could be useful for this research.

The investigators will research the fuel economy and VMT impacts of in-vehicle feedback systems in personal vehicles, with a particular emphasis on how to most effectively influence driver behavior. This research will examine the role that in-vehicle feedback systems play in influencing driver behavior (including fuel economy and VMT), and what features of these systems (e.g., type or layout of feedback, visual vs. auditory vs. pedal push-back) are key to

optimizing emissions reductions. The investigators will also examine the long-term fuel use impacts of in-vehicle feedback and driver training, and may explore whether vehicle technology affects driver response to in-vehicle feedback systems. The project will investigate traveler behaviors and quantify potential reductions in transportation emissions. Results will be used to develop policies that foster reduced emissions from transportation through effective use of on-board technologies, and complementary training.
Proposed level of funding: $300,000

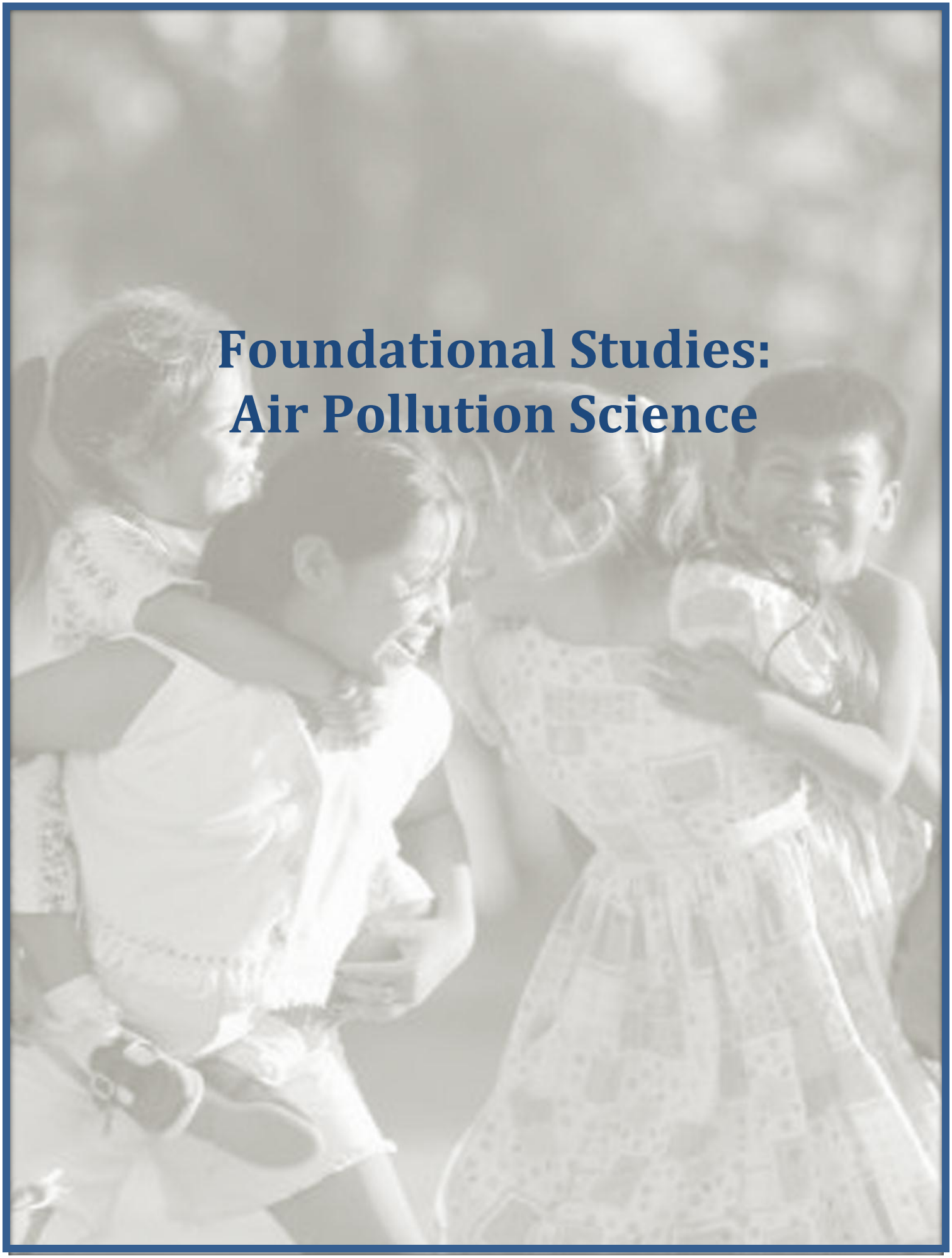
Consumer Attitudes to Low-Emission Vehicles

Objective: New advanced vehicle technologies, including those that reduce criteria pollutant and greenhouse gas emissions, continually evolve in response to consumer preferences and other market conditions. Total on-road fleet emissions will therefore depend on consumers' willingness to purchase and use light-duty vehicles integrating those technologies. This study's objective is to collect information about new light-duty vehicle purchases to understand consumer attitudes toward emission-reducing vehicle technologies.

Concept: Consumers ultimately shape light-duty vehicle designs by virtue of their new car and light truck purchases. New vehicle offerings integrate a range of emission-reducing technologies that vary in cost, complexity, and transparency, but it is currently uncertain how these technologies may influence vehicle purchase decisions or how consumer attitudes may evolve over time. While there is a robust literature related to consumer attitudes and willingness-to-pay for alternative fuel and low-emitting vehicles based on both stated and revealed preference surveys, the state of technology continues to progress and previous findings may no longer hold. However, current work at the state and federal levels (CEC, PEVC, DOE) regarding electric vehicle adoption and travel behavior may be able to address certain portions of the market.

This study uses qualitative research techniques to assemble time-series data on the purchasing process and ultimate decisions of new light-duty vehicle buyers over a multi-year period. Interviews will be structured to identify and evaluate factors influencing new-vehicle purchase decisions, with particular focus on consumer awareness of and attitudes toward emission-reducing technologies and alternative-fuel vehicles. The sample will be stratified to ensure sufficient coverage of various geographic locations, vehicle types, and demographic characteristics. These interview findings will be evaluated within the context of broader market conditions and for any trends over time. Study results will be useful to policymakers and vehicle manufacturers seeking to understand the factors that stimulate and constrain sales of low emission and alternative-fuel vehicles.
Proposed level of funding: $250,000

Foundational Studies: Air Pollution Science



FOUNDATIONAL STUDIES: AIR POLLUTION SCIENCE

Air pollution science is the foundation of efforts to understand and address air quality issues. For more than 40 years, the ARB and the University of California have partnered to make California a center of pioneering research into air pollution science. The scientific and technical knowledge gained through that research, coupled California's comprehensive air pollution control programs, have made possible the dramatic improvement in California's air quality.

Understanding the chemistry which leads to the formation of air pollution was a research goal of Dr. Arie Haagen-Smit, ARB's first chairman. ARB has continued to fund research examining the chemistry occurring in the atmosphere. Air quality field studies provide vital data on the composition, formation and transport of air pollution in California. Knowledge developed from such field studies helps to improve essential analytical tools such as air quality models used to predict atmospheric processes. Over several decades, 40 ARB-sponsored field studies have provided information critical to the design and implementation of California's air pollution control programs. ARB funding has also contributed to the body of scientific knowledge about the health effects of air pollution, especially fine particulate matter (PM2.5) and ozone.

Air pollution studies span a wide variety of academic disciplines. Health studies, air quality field studies, air quality model improvements, refinements to the emissions inventories, development of new emission control technologies, improved measurement methods, and assessments of the effectiveness of new technologies all provide part of the scientific foundation for air pollution control programs. Valuable work in these areas is funded by the United States Environmental Protection Agency (U.S. EPA), National Science Foundation, and Department of Energy, as well as international partners. Although scientists throughout the world work to better understand air pollution and its impacts, ARB's funded research into air pollution science still plays a key role in addressing specific California needs.

ARB shares responsibility for the following ambitious goals:

- ***Protecting Health by Reducing Exposure to Air Pollution:*** Conduct health-based research in support of ambient air quality standards, with special attention to protecting the health of infants and children, and evaluate strategies to reduce public exposure to air pollutants.
- ***Attaining Air Quality Standards****:* In conjunction with air districts develop State Implementation Plans (SIPs) for the ozone and PM2.5 standards that demonstrate attainment by mandated deadlines.
- ***Meeting Greenhouse Gas Reduction Targets:*** Develop and implement a plan to reduce California's greenhouse gas emissions to 1990 levels by 2020 and work to reach the goal of reducing 2050 emissions to 80 percent below the 1990 baseline.

The findings of ARB's research efforts can bridge gaps in scientific knowledge, and guide and support environmental policies and regulatory development. ARB's research program is

designed to help California meet the continuing challenge of improving air quality and reducing greenhouse gas emissions.

Protecting Health by Reducing Exposure to Air Pollution

ARB funding has contributed to the body of scientific knowledge about the health effects of air pollutants, particularly PM2.5 and ozone. The most significant ARB-funded contribution has been the Children's Health Study, which has provided the majority of available data on the responses of children to both long- and short-term exposure to air pollution. Other ARB-funded epidemiological contributions have addressed the influence of long-term air pollution exposure on mortality, and short-term air pollution exposures on asthmatic children.

In addition, ARB-funded human and animal exposure studies have made significant contributions to the understanding of the biological pathways and mechanisms through which air pollution exposure leads to clinically relevant health responses in healthy and asthmatic individuals, particularly those pathways involving ozone and particulate matter. For example, ARB studies have investigated how human health responses to particulate matter differ with season, region, and density (i.e., rural vs. urban sites), and have examined the long-term effects of exposures to elevated concentrations of ozone and particulate matter during early childhood.

ARB is also investigating the associations of asthma morbidity with exposure to air pollutants, including primary and secondary organic aerosol, NO_X, NO_2, CO, and ozone, and characterizing emissions and exposure impacts in low-income communities near ports and heavily trafficked roads. Still, a number of research questions remain about the mechanisms that induce adverse health effects from air pollution. While it is beyond the ability of ARB's research program to fund major studies of this type, U.S. EPA and the Health Effects Institute (HEI) are funding valuable mechanistic research on air pollution and health.

The emphasis of ARB's research on health and exposure is to apply the research questions to California conditions. One example is to explore the differences in public exposure at the statewide, regional, and community levels. Another area of research is the monitoring of changes in exposures to air pollution as regulations are put in place or other factors affecting exposure change with time. Research is also needed to better understand factors impacting personal exposure to air pollution, exposures of vulnerable individuals such as asthmatic children, and assess potential mitigation measures.

The three research projects for FY 2011-2012 are focused on identifying current air pollutant exposures in California and evaluating the effectiveness of filtration in reducing those exposures.

Reducing Indoor Exposure to Air Pollution

Objective: Newly constructed homes in California are now required to have mechanical ventilation systems to assure that sufficient outdoor air is brought into the home, but the most economical and widely used mechanical system does not filter the incoming outdoor air at all. The objective of this project is to measure the effectiveness and energy use of combinations of mechanical ventilation systems and filtration systems to identify compatible low-energy systems that are most effective at reducing indoor exposures to indoor, and incoming outdoor, pollutants.

Concept: In part to address indoor air quality issues, new California homes are now required to have mechanical ventilation. Some such systems include filtration, but the most economical (and widely used) low energy systems do not filter the incoming air or filter it poorly. Because new construction often occurs near busy roadways, and because newer land use policies encourage infill developments in urban areas, different mechanical ventilation and high efficiency filtration technologies need to be assessed to examine how much they affect Californians' exposures to ambient pollutants, along with their energy costs, so that the most cost-effective, health-protective systems can be specified for new construction.

Studies have shown that high efficiency filtration (MERV 13-16) can be very effective in reducing particles indoors, but only very limited high efficiency options are available for residences, and there is often an energy cost, especially for those associated with central mechanical systems. Effective methods of filtration of ozone and VOCs for residences are also desirable, but options are very limited for the residential market. Filter manufacturer involvement is needed to provide a better range of options for both particle and VOC filtration. The California Energy Commission has funded has funded two related projects in this area and is expected to be a collaborator. The proposed project would build on the Energy Commission's projects but with a greater focus on the indoor exposure reductions that can be achieved.

The investigators will measure levels of particles and ozone or other VOCs inside and outside of either a test home or newly constructed homes with selected types of mechanical ventilation systems and filtration technologies to determine how these units affect infiltration of, and residents' indoor exposures to, ambient pollutants. The investigators will test combinations of at least four different types of mechanical ventilation systems and six types of filtration devices. The most promising types of mechanical systems and filtration technologies available on the market for California homes will be included in the study, as well as some new models made available by manufacturers. Energy use will also be recorded, so that the most health protective and energy-efficient units can be identified. The use of a test home and/or similar newly constructed homes is required for this study in order to allow proper assessment and comparison of the different technologies. The results of this study will identify mechanical ventilation and filtration systems that are both health-protective and energy-efficient that can be specified for new homes and homes of people with severe asthma or other respiratory conditions.

Proposed level of funding: $1,250,000

Benefits of High Efficiency Filtration to Children with Asthma

Objective: Particulate matter and ozone can cause or exacerbate asthma and other chronic respiratory diseases in sensitive individuals. The objective of this study is to: measure the indoor, outdoor and personal exposures of children with severe asthma or other respiratory conditions; determine whether the use of high efficiency filtration in their homes can effectively reduce their exposures to air pollutants and other asthma triggers; and assess whether their symptoms and health impacts are reduced.

Concept: Studies have been conducted that show associations of estimated exposure to ambient particulate matter (PM) and ozone with the development or exacerbation of asthma. However, little is known regarding the day-to-day personal exposures of sensitive sub-populations to PM and ozone. Additionally, while high efficiency filtration has been shown to significantly reduce indoor concentrations of PM in most cases, the use of high efficiency filters has not been fully explored as a potential mitigation measure to reduce exposures and health impacts from PM and ozone in homes of those with asthma.

Previous studies have largely examined the effectiveness of measures to address long-known triggers such as correcting cockroach and moisture problems, using bed and pillow covers to reduce exposure to house dust mites, and educating family members regarding avoidance of cigarette smoking in the home. The effectiveness of such measures showed mixed results in reducing symptoms across studies. A few studies have included filtration, but typically used portable filtration devices that were not necessarily high efficiency filters. The California Department of Public Health (CDPH) has studied asthma and has developed a substantial asthma reduction program that has included grants to local communities for asthma intervention; CDPH is a likely collaborator for this project.

The investigators will measure personal, indoor and outdoor exposures of 300 children with asthma, chronic bronchitis or other serious respiratory disease to PM, ozone and possibly other pollutants known or suspected of triggering asthma. They will obtain symptom and health status information via questionnaires, interviews, and medical records if available. Investigators will then examine the effectiveness of high efficiency filtration (including ozone removal media plus catalyst) in reducing exposures, symptoms, and health impacts in the study population. This could include retrofitting one-third of the homes with in-duct high efficiency filters; providing one to two high quality, high efficiency portable air cleaners per home in another third of the homes; and providing asthma trigger reduction information but no filtration in the third group of homes.

Personal, indoor and outdoor exposures would be measured again after the intervention for comparison to the pre-mitigation exposure levels, and pre- and post-questionnaires and interviews would be used to assess reductions in symptoms and health impacts. The results of this study will document the extent to which high efficiency filtration can reduce exposure to asthma triggers and the associated symptoms and health impacts. It may also identify ways to reduce medical costs for those with severe asthma or other chronic respiratory conditions.
Proposed level of funding: $2,000,000 - $3,000,000

Reducing Air Pollution Exposure in Passenger Vehicles

Objective: Exposures to vehicle-related pollutants have been linked to premature death and exacerbation of various respiratory and cardiovascular diseases. Some of the highest human exposures to certain pollutants and a large fraction of total daily exposure occur while traveling on roadways for much of the population. The objective of this study is to test different types of high efficiency filters in vehicles and school buses to identify cost-effective techniques to reduce in-cabin particle levels and thus reduce the population's exposure to vehicle-related air pollutants.

Concept: Ultrafine particles inside vehicle passenger cabins have been shown to be 10 times higher than ambient levels and contribute up to 30-50% of total daily exposure for a typical California commuter. This high in-cabin exposure is due to the vehicle's close proximity to relatively undiluted emissions. Among commuters, school children riding in school buses are considered especially vulnerable due to their immature respiratory systems and greater breathing rate per body weight. Tremendous progress has been made in reducing vehicular emissions by tightening emission standards and retrofitting buses, but the potential to further reduce exposure to vehicle-related pollutants by reducing the proportion of on-road pollutants penetrating into vehicle cabins has largely been overlooked. Previous work by various investigators has shown that setting vents on recirculation and the use of cabin filters can reduce in-vehicle particles by 80-95%. However, CO_2 from exhaled breath of passengers can build up quickly and exceed Cal-OSHA personal exposure limits in cars when vents are set on recirculate and windows are closed. Using high efficiency filters is one low cost approach that can reduce exposure when vents must be opened.

Development of cost-effective techniques to reduce on-road exposures is a potential, largely unexplored strategy to reduce these critical population exposures. The investigators will determine the degree of fine and ultrafine particle reduction: 1) inside passenger vehicles equipped with various types of high efficiency cabin air filters; 2) inside school buses equipped with a high efficiency cabin air filter; and 3) inside school buses equipped with a HEPA air purifier.

Twelve passenger vehicles and six school buses will be used for testing along freeways and urban streets. Particle number and size distribution, PM2.5, CO, CO_2, meteorological parameters and traffic activity will be monitored using real-time instruments. The investigators will identify the filters and ventilation system operational conditions that achieve the greatest exposure reduction inside the vehicles. This project will identify the most effective approach to reducing in-cabin exposures to ultrafine and fine particles, which can be incorporated into guidelines or regulations to protect health.
Proposed level of funding: $150,000

Attaining Air Quality Standards

In the coming decades, California must comply with stricter air quality standards as well as ambitious greenhouse gas reduction targets. Although ARB has made significant progress in reducing ground level ozone, PM2.5, and other pollutants, meeting federal and state ambient air quality standards will be challenging. Increasing transport of these pollutants from Asia and other areas will make attainment of more stringent federal air quality standards difficult for both urban and rural areas of California. Understanding the sources of pollution transported across the Pacific Ocean is a challenging research area and one that has been identified for funding this year.

ARB has a long-standing research commitment to support development of State Implementation Plan (SIPs) that show how California will meet federal air quality standards. Efforts continue to improve estimates of emissions and improve air quality modeling, both of which are critical to the design of SIPs and effective regulations. Ongoing research includes developing an accurate biogenic VOC inventory, which is critical to SIP development as air quality impacts of biogenic VOCs relative to those of man-made VOCs are increasing. An important research need identified by the Dairy Committee of the San Joaquin Valley Ag Tech Committee is to more fully understand VOC emissions from dairy silage operations and methods to mitigate them.

Building upon the success of the CalNex 2010 field study, a major collaboration conducted with the National Oceanic and Atmospheric Administration (NOAA), ARB has an existing research contract with NOAA to synthesize the scientific results of the CalNex 2010 to support California's air quality and climate programs. For this year, ARB has identified continued funding for analysis of CalNex 2010 data collected in the South Coast Air Basin and the San Joaquin Valley on the contribution of organic aerosols to PM2.5 pollution, a contribution that is poorly understood and underrepresented in existing air quality models.

Technology has historically played a central role in reducing emissions to meet air quality standards and must support California's transition to a low carbon economy with minimal emissions of smog forming pollutants. It will also be important to monitor and measure the impact of new technologies. An important research area identified this year is to assess the new technologies introduced in the market place in response to ARB regulations on diesel engines.

There are four research projects for FY 2011-12 to improve the scientific foundation that will support future SIP efforts to demonstrate attainment with stricter air quality standards. First, analysis of ozone and related tracers will improve our understanding of the contribution of long-range transport of air pollutants into California. A second project will improve dairy silage VOC emission estimates and focus on mitigation options. Third, field measurements and experimental results will illuminate the contribution of organic aerosols to particulate pollution and improve state-of-the-art air quality models. The fourth study will investigate the durability of emissions controls being used for exhaust aftertreatment for newer heavy-duty diesel trucks.

Long Range Transport of Air Pollutants into California

Objective: Pollutant transport from the growing Asian economic region raises background air pollution levels in California potentially affecting the ability to comply with air quality standards. This project will establish a small monitoring network devoted to detecting ozone and particulate pollution arriving over the Pacific Ocean.

Concept: Recent research indicates that air pollution transported from Asia is driving increases in background ozone and PM in California, with the potential to contribute to exceedances of State and Federal 8-hr ozone air quality standards. A field study coupled with modeling is needed to refine understanding of present and future impacts on ozone attainment in California. Aircraft data from ICTC2K2, ARCTAS-CARB, and CalNex 2010 all show Asian pollution, including ozone, arriving over California. Analyses of ground samples have shown widespread and persistent Asian PM in clean rural areas of the State. One study of ozone in far northern California computed as much as 80 percent of springtime ozone (8-hour averages) in the northern Sacramento Valley may be imported with air coming over the Pacific Ocean, which contains ozone from Asia.

ARB-sponsored research has identified specific tracers for Asian PM, detectable even in urban California, which can be used to identify Asian air masses. This project will measure both ozone and related tracers for direct analysis and for comparison with global pollution transport models. A small monitoring program will add instrumentation to existing monitoring facilities and ongoing programs, plus utilize other existing non-ARB data sources, such as NOAA ozonesonde releases. The network will consist of two pairs of stations, one using an upwind site in the North Coast Ranges matched with an existing ARB site in the Sacramento Valley, and one using an upwind site in the Central Coast Ranges matched with an existing SJVAQMD site in the San Joaquin Valley.

Measurements in addition to ozone will include gases and aerosols known to be tracers for long range ozone chemistry and Asian pollution sources. The tracer data will be used to validate transport modeling for both chemistry and source attribution. ARB will work with a high-level global modeling collaborator (NOAA, NASA, or similar). ARB will use the monitoring data in conjunction with global chemical transport models to confirm and refine long range ozone transport chemistry, source attribution, and upwind emission estimates in order to track and predict how Asian emissions growth impacts California air quality.
Proposed level of funding: $500,000

Dairy Feed Management Practices to Reduce Emissions

Objective: Meeting increasingly stringent ambient air quality standards for ozone is a challenge in the San Joaquin Valley (SJV). Silage from dairy operations contributes significantly to ozone and application of effective mitigation efforts would help the San Joaquin Valley meet its air quality goals. This project will characterize emissions during the entire silage process and under the varying conditions of California dairies to identify high-emission conditions and provide the necessary information to focus mitigation efforts.

Concept: Dairy operations are known to be significant emission sources of volatile organic compounds (VOCs) in the SJV. Many of these VOCs contribute to the formation of ground-level ozone, for which the SJV is currently in non-attainment for both state and federal ambient air quality standards. Silage has been identified as one of the primary VOC emission sources within dairy operations, capable of producing significant quantities of ground-level ozone. Previous work has shown the ozone formation potential from corn silage to exceed that of light-duty gasoline vehicles to the SJV. Additional work has identified cattle feed, of which silage is a main component, as having the greatest potential for VOC reductions from dairy operations. An emission model has been developed to estimate the alcohol emissions from silage. However, this model does not address other VOC emissions, may not accurately consider emissions over the entire feeding process and input data is not available for the multitude of silage types in use within California.

The project would examine specifics about the silage process and how it relates to emission of specific VOC species, particularly those with high ozone forming potential. The temporal emission profile of VOC species will be characterized throughout the feeding process. Different sampling approaches (*e.g.,* wind tunnel and flux chamber) will be inter-compared providing insight and context into the accuracy of previous measurement efforts. The results of this study will be used to assess current silage management and feed distribution practices as they relate to VOC emissions and provide information to identify the most effective mitigation measures with the intended outcome of reducing ground-level ozone in the SJV.
Proposed level of funding: $400,000

Contribution of Organic Aerosols as a Component of PM2.5 Pollution

Objective: Although organic aerosols, and specifically secondary organic aerosols (SOA) formed from oxidation of gaseous precursors, constitute a large fraction of the submicron particulate mass and are responsible for significant health and climate effects, a substantial gap remains between predicted and field measurements of SOA concentrations. The objective of this research project is to compare the amount and composition of secondary organic aerosols formed during CalNex, as determined by HR-ToF-AMS, against state-of-the-art SOA models with the aim of improving modeling of the concentration, composition and evolution of SOA in California.

Concept: Recently published results from field studies have suggested that organic aerosols, and in particular, secondarily formed organic aerosols, comprise a large portion of submicron aerosols in the South Coast Air Basin and the San Joaquin valley. State-of-the-art SOA models, however, do a poor job of predicting the sources, evolution and concentrations of this SOA, which greatly limits the ability of regulators to develop effective control strategies. The Jimenez Group has participated in several field experiments in California with the specific goal of characterizing sources, composition and evolution of organic aerosol (OA). During the most recent study in California, CalNex 2010, a hi-resolution Time-of-Flight Aerosol Mass Spectrometer (HR-ToF-AMS) and complementary instrumentation were deployed for four weeks in Pasadena. This work overlapped significantly with broader CalNex 2010 efforts carried out by groups from NOAA and many universities (>30 alone at the Pasadena site), producing extremely comprehensive data sets for both the South Coast Air Basin and the San Joaquin Valley (Bakersfield site).

The proposed study would utilize these measurements in the development of improved SOA models, effectively leveraging several million dollars' worth of data collection and analysis work from the CalNex 2010 study. To test state-of-the-art SOA models, experimental characterization of OA will be combined with measurements of SOA precursors and oxidants carried out by other researchers. The precursor and oxidant data will be input into these models to provide predictions for the concentration, composition and volatility of SOA at the field site; the resulting predictions will be compared against SOA characteristics determined experimentally. Given the scope and the sophistication of the gas-phase and particle-phase measurements carried out during CalNex 2010, the proposed research will test and constrain SOA models at a level of detail that has not been possible before. The results of this study will be used to help identify sources of SOA and improve models that quantitatively predict the evolution of SOA, which will aid in the development of effective strategies to reduce SOA pollution in California and in predictions of future climate change.
Proposed level of funding: $350,000

Investigate the Durability of Diesel Engine Controls

Objective: New emissions standards for heavy-duty vehicles implemented for PM and NO_X in 2007 and 2010 respectively are leading to the introduction of exhaust aftertreatment in diesel trucks. These include diesel particle filters (DPFs) and selective catalytic reduction (SCR). The objective of the current study is to make measurements from a large number of in-use trucks to characterize the effect and durability of these aftertreatment devices.

Concept: DPFs and SCRs drastically lower harmful emissions from heavy-duty diesel trucks. However, since they are relatively new, their durability in the real world are not yet fully known. It is also unknown whether tampering is occurring. Without fully functioning aftertreatment a diesel truck would emit tens to hundreds of times higher emissions, negating the air quality benefit of the new engine standards. ARB fleet rules are accelerating the introduction of DPFs and SCRs in the truck fleets in and around the major ports in the state. Several investigators have used chase vehicles, remote sensing and other methods to characterize a drastic reduction in the overall diesel emissions resulting from this rule. To

answer the question about durability of the aftertreatment the existing data can be mined. But since the introduction of the aftertreatment is still a relatively new occurrence it is important to continue the studies already undertaken.

The investigators will use the current dataset to explore the durability issue. The project will also include continued measurement of emissions from heavy-duty trucks. These measurements are envisioned to take place on-road from several thousand trucks each year over a period of several years. While the measurement method is yet to be determined several possibilities exist, such as remote sensing, or collecting a small air-sample containing exhaust from individual vehicles (several methods exist to accomplish this). Data will include measurements of criteria pollutants, such as carbon monoxide, total hydrocarbons, NO_X, and PM as well as nitrogen oxide, nitrogen dioxide, and black carbon at a minimum. Particle number and size distribution would be valuable additional measurements. The results from the study will provide real world data on heavy-duty aftertreatment durability, which will be an important factor in inventory calculations for heavy-duty emissions. If the durability is less than expected the study will also shed light on how to improve the overall effectiveness of aftertreatment and realize the expected emission reductions.
Proposed level of funding: $250,000 – $300,000

Meeting Greenhouse Gas Targets

The emphasis of ARB's foundational research on greenhouse gases is to explore potential new emission reduction strategies, ways to improve emissions estimates, and methods to verify emissions reductions over time.

ARB staff has partnered with the California Energy Commission (CEC) and the Department of Food and Agriculture on a multi- year research effort examining nitrous oxide (N_2O) emissions from the application of fertilizer to agricultural soils. These projects have initially focused on baseline emissions estimates and the validation of models to accurately estimate emissions based on biological, meteorological, crop, and soil specific information. The next step is to examine the emissions reduction impacts of mitigation options for important California crops.

ARB has also partnered with the CEC to improve the state's emissions inventory for methane and other GHGs using tall tower measurements. CEC has been the main supporter of the existing towers to date and with the evolving agency roles ARB will take over that role and coordinate with on-going and future CEC projects. Recent studies show that the N_2O emissions inventory may be underestimated by approximately 66% in central California. ARB has identified the importance of continuing the tall tower measurements and recognizes the importance of expanding this capability into the South Coast Air Basin. In addition, the concurrent measurement of VOCs will allow us to attribute greenhouse gas emissions to specific sources. ARB also has sponsored a multi-year research study, *Black Carbon and the Regional Climate Impact of California*, which has shown a 50 percent reduction in black carbon over the past twenty years due mainly to reductions from diesel engines. The study has examined regional climate response to black carbon emissions in the state, to serve as a basis for policy and control strategies. The investigators have proposed the addition of funding to

allow analysis of solar radiation data over the same twenty year period to examine the impacts of the reduced black carbon.

The following four research projects for FY 2011-12 will improve the scientific foundation that supports California's efforts to meet near and long-term greenhouse gas emission reduction goals. The first effort will improve our understanding of emissions of high-global warming potential gases from waste insulation foams in landfills. A second project will focus on mitigation options to reduce N_2O emissions from the application of fertilizer to agricultural soils. Third, ARB will continue critical support of tall tower measurements in Northern California, expand this capability to Southern California, and add VOC measurements for better source attribution. Finally, an existing research contract will be augmented to analyze solar radiation data and illuminate the role of black carbon emissions in California's weather and climate.

Emission of Potent Greenhouse Gases from Appliance and Building Waste in Landfills

Objective: High-global warming potential (high-GWP) greenhouse gases (GHG) contained in landfilled insulating foam may potentially be a significant source of GHG emissions, estimated at 2.6 million metric tonnes of carbon dioxide equivalents ($MMTCO_2E$) in California in 2010, and expected to almost double to 4.8 $MMTCO_2E$ annually by 2020. However, these estimates are theoretical, as no waste foam GHG emissions have been measured from California landfills, and research is necessary to confirm the extent to which waste foam in landfills is biologically attenuated or captured and reduced by landfill gas collection and combustion systems. The objective of this research is to determine the high-GWP GHG emissions from waste insulating foam in landfills.

Concept: Waste insulating foam from refrigerator-freezers and building insulation that has been landfilled is assumed to be a significant source of GHGs because the insulation contains foam expansion agents of chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), and hydrofluorocarbons (HFCs), which have high-GWPs ranging from 700 to 4750. However, previous limited studies suggest that actual foam GHG emissions from landfills may in fact be negligible. Laboratory research in Denmark suggests that much of the CFC foam expansion agent in the landfilled foam is biologically attenuated and reduced prior to emissions (HCFCs and HFCs are not attenuated).[14] Additionally, limited landfill gas studies in Canada suggest that in a landfill with a methane gas collection and combustion system in place, up to 95% of the foam expansion agents are reduced to non-global warming constituents from auto-decomposition at high combustion temperatures (1150 to 1350 °F).[15]

14 Scheutz, C., and Kjeldsen, P. Capacity for Biodegradation of CFCs and HCFCs in a Methane Oxidative Counter-Gradient Laboratory System Simulating Landfill Soil Covers. Environmental Science & Technology, Volume 37, No. 22, November 2003, 5143-5149.

15 Environment Canada, Greer, A., and Cianciarelli, D. Characterization of Emissions from a 26 kWe Micro Turbine Fired with Landfill Gas. Shepard Landfill, Calgary, Alberta. Report ERMD 2004-02. January 2005.

An ARB-funded 2010 study on insulating foam GHG emissions in California confirmed the significant potential of GHG emissions from landfilled foam, but actual emission measurements from landfills were not part of the scope of work.[16] To address the uncertainty for this potential emissions source, the investigators will measure high-GWP GHG emissions from landfills known to contain waste insulating foam, measuring baseline levels at certain time intervals (to measure the effect of biological attenuation), and measuring landfill gas pre-combustion and post-combustion levels to determine magnitude of foam GHG emissions from a typical California landfill. Findings from this study will help determine if the business-as-usual process of disposing appliance and building waste foam into California landfills is a significant source of high-GWP GHG emissions and whether there is a need for any action to reduce these emissions.

Proposed level of funding: $200,000 - $300,000

Mitigation of N_2O Emissions from Agricultural Soils

Objective: The agricultural sector is the largest contributor of nitrous oxide (N_2O) both globally and in California, accounting for about 60% of anthropogenic N_2O emissions. Mitigation of N_2O from agricultural soils represents a viable opportunity to reduce GHG emissions from agriculture. This project will identify and quantify emission reductions of N_2O from potential mitigation measures for important commodities grown in California.

Concept: N_2O is produced from soil through microbial processes involving nitrogen compounds. Its emissions are thus closely related to soil nitrogen content, but highly variable due to impacts of numerous environmental variables that govern microbial activities such as soil properties, meteorological conditions, and crop management practices. There are five ongoing projects, coordinated among ARB, the California Energy Commission and the California Department of Food and Agriculture, to characterize baseline N_2O emissions from major California crops. Since agricultural systems are highly managed, N_2O emissions may be effectively reduced by adopting practices that increase nitrogen fertilizer efficiency, and consequently reduce nitrogen inputs into agricultural fields.

For example, a USDA study has shown that application of nitrification inhibitors in corn can reduce N_2O emissions by more than 50 percent. Several studies are also being carried out in California to investigate the effects of dripping irrigation, cover crops, and different forms of nitrogen fertilizers on N_2O emissions in tomatoes, almonds, and grapes. However, these are isolated studies in which the practices being tested are not necessarily the most effective ones and in some cases the studies are not focused on N_2O. ARB needs a systematic approach to quantifying reduction potential from the most promising mitigation options for the major crops in the state.

16 Caleb. 2010. Developing a California Inventory for Ozone Depleting Substances (ODS) and Hydrofluorocarbon (HFC) Foam Banks and Emissions from Foams. Prepared for California Air Resources Board (Research Contract 07-312). November 2010.

The purpose of this project is to test alternative management practices that hold the most potential for N_2O reductions from agricultural fields and are anticipated to be both economically and technically feasible. Such practices could include the use of slow release fertilizers, nitrification inhibitors, cover crops, dripping irrigation, and manure nitrogen. Field monitoring studies will be conducted to measure N_2O fluxes from major California crops managed under these selected practices, and the monitoring results will be analyzed with geochemical modeling to estimate the overall GHG budget. The management practices that are most effective in mitigating N_2O emissions will be identified in consultation with the agricultural stakeholders. This project is expected to provide critical information needed for the development of agricultural offset protocols.
Proposed level of funding: $400,000

Atmospheric Measurement and Inverse Modeling to Improve Greenhouse Gas Estimates

Objective: Although the majority of the greenhouse gas emission inventory (i.e. CO_2 emissions from fossil fuels) is well defined, methane (CH_4) and nitrous oxide (N_2O) emissions make up approximately nine percent of emissions and are still highly uncertain. This project will improve understanding of these potent greenhouse gases by utilizing tall tower measurements at Walnut Grove, Mt. Sutro, and a new site near Riverside and inverse modeling to estimate emissions by region and source type throughout the state. Comparison to ARB's current GHG estimate will identify areas where additional study will yield improved understanding of emission sources and potentially enable targeted mitigation efforts.

Concept: Emission estimates for CH_4 and N_2O are highly uncertain, particularly for agricultural N_2O estimates. Recent studies at tall tower sites show that N_2O emissions inventory may be underestimated by approximately 66% in central California. In addition, a pioneering study by ARB staff applied measurements of CH_4 and CO from a tall tower at Mt. Wilson to estimate CH4 emissions from the Los Angeles area and found agreement with the ARB CH_4 inventory to within ~ 30%. However, other recent airborne measurements and remote sensing of the South Coast area suggest that CH_4 emissions may be twice that of inventory estimates. This suggests that additional sites beyond Mt. Wilson are needed to quantify South Coast emissions. To date, CEC has been the main source of funding for these tall tower measurements but given the evolving agency roles, ARB will provide future funding and ensure coordination with on-going and future CEC projects.

The above results were generated by taking the ambient air measurements at two tall tower sites and converting them to GHG emissions estimates using inverse modeling, which can also provide source type contributions (i.e. fossil fuel or biological based emissions) for the covered areas. This level of comparison will not just point out uncertainties but enable refinement by identifying the sources most likely leading to that uncertainty. California has been on the forefront by utilizing tall towers and inverse modeling to estimate CH_4 and N_2O emissions for the central California area. As mentioned above, the results highlighted potential areas of discrepancies between the measurement data and GHG emissions inventory of 37% and 66% for CH_4 and N_2O, respectively, for central California. Based on this information, ARB can

consider inventory refinement for sources within the covered area but the data are limited and a more robust analysis on ARB's continuing measurements will improve our understanding.

The towers and associated inverse modeling would also provide a consistent time series of atmospheric measurement data for evaluating trends as greenhouse gas regulations are put in place. This project will gather measurements of greenhouse gases at three tall tower sites and apply inverse modeling and Bayesian statistical techniques to both those measurements and measurements from ARB's monitoring network throughout the state and estimate GHG emissions by air basin with source specific information. The goal is to construct GHG emission estimates based on atmospheric measurements and compare the results to ARB's GHG inventory. The results of this study will be used to determine regional and source uncertainties in the CH_4 and N_2O inventories in order to improve our GHG estimates and correctly target mitigation options to meet our long term GHG reduction goals. Continued funding of the towers will also provide a consistent time series of atmospheric measurements that could be used to evaluate the impact of greenhouse gas reduction strategies.
Proposed level of funding: $680,000

Using VOC Measurements at Tall Towers to Distinguish Greenhouse Gas Sources

Objective: As California moves forward to reduce greenhouse gases collection of atmospheric measurements can be used to validate the state's greenhouse gas inventory and verify changes in emissions anticipated from the state's greenhouse gas reduction measures. This project will measure a suite of volatile organic compounds (VOC) at the Walnut Grove tall tower to serve as tracers to help distinguish between emission sources of the greenhouse gases already measured at the site. These data, when combined with source apportionment analysis, will provide valuable GHG emission estimates that can be used for improving the inventory, verifying reductions, and planning future mitigation strategies.

Concept: Atmospheric measurements are key to validating the greenhouse gas inventory, verifying the impact of reduction strategies, and identifying sources of greenhouse gas emissions. Gathering atmospheric data at tall towers and using tracer species is one promising method to apportion emissions to sources. California's existing two towers have generated valuable data on emissions but have not been able to provide source specific emission estimates. A recent study during the CalNex project suggests that different sources emit specific mixtures of VOCs along with GHGs, potentially enabling attribution of emissions to a source category. This project will add VOC tracers to the suite of measurements at the Walnut Grove tall tower in an effort to attribute GHG emissions to specific sources (e.g. oil/gas facilities, dairies, and automobiles). These results are valuable in targeting mitigation options, identifying areas in need of inventory improvements, and determining impacts of current GHG reduction strategies.
Proposed level of funding: $250,000

The Role of Black Carbon in Climate Change Mitigation: Analyses of Solar Radiation Data

Objective: The investigators will analyze surface solar radiation flux measurement data to explore the link between policies on diesel emissions and climate mitigation. The project has the potential to verify with observational evidence the total radiation benefit of combined black carbon (BC) and sulfur controls (which is thought to have a counteracting impact to black carbon) for the first time.

Concept: Black carbon particles are part of the total mix of particulate matter (PM) released during incomplete combustion of carbon-based fuel. BC and other PM constituents all contribute to these adverse health effects. Black carbon's high capacity for light absorption and its role in key atmospheric processes link it to a range of climate impacts, including increased temperatures, accelerated ice and snow melt, and disruptions in precipitation patterns. While it is widely recognized that reducing black carbon will have climatic benefits, efforts to evaluate the actual impacts on surface radiation of black carbon reductions have been limited. ARB's research study, *Black Carbon and the Regional Climate Impact of California*, has observed roughly a 50 percent reduction in black carbon measured at IMPROVE sites throughout California over the past twenty years. This agrees with the expected emission reductions associated with California's diesel emissions control program. Given the large uncertainty in model estimates of BC emissions from various sources, their atmospheric concentrations and optical properties, it would be highly advantageous to have empirical data to validate model predictions.

The CIMIS network provides hourly measurements of the surface solar flux at stations distributed throughout California. The investigators will use the CIMIS dataset in conjunction with AERONET measurements to determine long-term trends in surface brightening or dimming. They will adopt a two-pronged approach to separate trends in clear-sky solar flux from the cloudy-sky solar flux. The Coefficient-of-Haze (COH) data provide a direct measurement of the visibility conditions constrained by carbonaceous aerosols. The investigators will also compare 20-year trends in COH and solar flux in each of the California basins to provide a direct link between the expected surface brightening, observed solar flux, and reduction in BC emissions in California. The results of this study will provide insights on the role of BC aerosols in California's weather and climate, and could help remove barriers to decision-making involving BC and climate change policy.
Proposed level of funding: $25,000