California Environmental Protection Agency

Air Resources Board

PLANNED AIR POLLUTION RESEARCH

Fiscal Year 2005-2006

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Summary

This report presents the Air Resources Board's planned air pollution research for the fiscal year 2005-2006. Thirty-one projects are proposed. Twenty-six projects are recommended for funding and five are recommended if funding is available. This research portfolio is organized into five main areas of research: Environmental Justice, Health and Welfare Effects, Exposure Assessment, Technology Advancement and Pollution Prevention, and Global Air Pollution. This annual plan proposes research in these five areas, with a primary emphasis on community monitoring, particulate matter (PM) health effects, exposure assessment and control of fine and ultrafine PM, and greenhouse gas emission estimation and mitigation. The proposed budget for the recommended projects is approximately $6,600,000.

Introduction

The Air Resources Board (ARB) sponsors a comprehensive program of research addressing the causes, effects, and possible solutions to air pollution problems in California, and provides support for establishing ambient air quality standards. The Board's research program was established by the Legislature in 1971 (Health and Safety Code Sections 39700 et seq.) to develop a better understanding of the various aspects of air pollution, including air pollution's effects on health and the environment, the atmospheric reactions and transport of pollutants, and the inventory and control of air polluting emissions. In recent years, several legislative mandates have expanded and further defined the scope of the program.

The ARB's mission to protect California's public health, welfare, and ecological resources is supported through a Strategic Plan for Research covering the years 2001-2010. The Strategic Plan is based on the ARB's regulatory priorities for the next several years and provides direction for the ARB's research program. The four main areas of research identified in the Strategic Plan are: Health and Welfare Effects, Exposure Assessment, Technology Advancement and Pollution Prevention, and Global Air Pollution. They are also the categories that guide this plan. These areas encompass the comprehensive mission of ARB's air pollution research. The Strategic Plan can be found at http://www.arb.ca.gov/research/apr/apr.htm.

The proposed research projects are not intended to be exhaustive or exclusive. Unanticipated opportunities, unique or innovative study approaches, or urgency may lead to consideration of other projects.

Objective of the Research Program. The goal of the research program is to provide the timely scientific and technical information that will allow the Board and local districts to make the public policy decisions necessary to implement an effective air pollution control program in California.

Process for Developing this Research Plan. The Board sends out a public solicitation inviting and encouraging the public to contribute ideas for project consideration. Members of the public, the academic community, and ARB staff submit research ideas. To aid in the evaluation, the Board's Executive Officer established internal committees to review research ideas. Proposed projects were examined for relevance to regulatory questions facing the Board and modified as necessary. Committee members then prioritized candidate projects in order of urgency and importance. The Board's scientific external review committee, the Research Screening Committee (RSC), which was established by the Health and Safety Code, reviewed these candidate projects. The list of projects, along with comments from the RSC, was forwarded to the Executive Research Review Committee, whose members are the Executive Officer, her three deputies, and the Chief of the Research Division. The Executive Research Review Committee reviewed all of the proposed projects and established project priorities. Selected projects are then placed into two categories: 1) those that are recommended for funding, and 2) those that are recommended if funding is available. The Research Screening Committee reviewed the selected projects and recommended the Plan to the Board.

Implementation of the Plan. The next step for projects approved in the plan will be their development into full research projects. The submission and selection of an idea does not guarantee a resulting contract for the submitter. Rather, the ARB is required to consider public California universities for expertise to execute these projects. If the universities do not possess the expertise, then a public solicitation is issued or a sole source contract is awarded. There is a list serve that individuals can subscribe to for receiving updates on research activities. Additional information can be found at http://www.arb.ca.gov/listserv/research/research.htm.

***Research Budget*.** The 26 recommended projects total approximately $6,600,000. The allocations for the proposed recommended projects among research categories are as follows:

RESEARCH CATEGORY	**BUDGET**
Environmental Justice	$1,150,000
Health and Welfare Effects	$2,410,000
Exposure Assessment	$1,625,000
Technology Advancement and Pollution Prevention	$ 500,000
Global Air Pollution	$ 955,000
TOTAL	$6,640,000

***Project Cosponsorships*.** The Research Division is continually looking for cofunding opportunities and other ways to leverage the state's research dollars. This effort allows the ARB to be part of projects and studies that may otherwise be out of the state's fiscal reach. ARB has had great success in working with other research organizations and has been part of multimillion-dollar studies with nominal cash contributions. Several of the projects in this plan have either confirmed or have potential cofunding dollars included in the cost category.

Summaries of Past Research. Ongoing research projects and projects completed since the beginning of 1989 are summarized in the Research Division's publication, Air Pollution Research, which is available at http://www.arb.ca.gov/research/apr/past/past.htm.

Electronic copies of all of the Research Division's final reports are available for downloading at the same web site.

RESEARCH PROJECT DESCRIPTIONS

ENVIRONMENTAL JUSTICE – *Recommended Projects*

HEALTH AND WELFARE EFFECTS

Human Health Effects – *Recommended Projects*

Recommended if funding available

Emission Inventory – *Recommended Projects*

Recommended if funding available

Personal and Indoor Exposure – *Recommended Projects*

Recommended if funding available

TECHNOLOGY ADVANCEMENT AND POLLUTION PREVENTION

Clean Air Technologies – *Recommended Projects*

GLOBAL AIR POLLUTION – *Recommended Projects*

TITLE: **Environmental Justice Saturation Monitoring of Selected Pollutants in Wilmington, California**

BACKGROUND: Air quality data are essential to characterize a community's exposure to air pollutants; however, air quality data (criteria pollutants and air toxics) collected at any environmental justice (EJ) community are very limited, typically at relatively few (one to five) locations due to the cost of traditional monitoring technologies. Thus, there is a concern that air quality monitoring location(s) may not reveal exposure to hot spots. In addition, the spatial resolution of most air quality data is relatively coarse (a single monitor for tens of square miles) compared to the spatial resolution of socioeconomic status (SES) data. To capture real exposure in the community, air quality data of finer spatial resolution that are compatible with SES data are needed.

PREVIOUS WORK: In order to address these issues, the ARB is currently sponsoring a project being conducted by Professor Manuel Pastor of the University of California, Santa Cruz that will develop a framework that takes into account cumulative exposure, a more comprehensive model of vulnerability at the community level including environmental, demographic, and SES factors, and develop a screening tool for regulators and others to identify areas in need of special policy attention and community outreach.

OBJECTIVES: The objectives are to: 1) complement the UC Santa Cruz project and provide an air quality data set that is of comparable spatial resolution as SES data for EJ analysis, 2) collect spatially resolved data in order to identify hot spots of selected pollutants, their magnitude and spatial extent, and relative importance to regional background, 3) collect data of sufficient spatial and temporal resolution to allow comparison with fine-scale modeling results, and 4) demonstrate the use of low cost monitoring technologies.

DESCRIPTION: Low-cost monitoring technologies such as passive monitors will be used in this project to collect data on selected toxics in Wilmington at different locations each season or for a long period (one year is desired). The selected monitors will be validated before and during the field study against conventional monitoring technologies for accuracy and precision. The monitoring sites to be determined, including hot spot identification, will be determined based on criteria defined by ARB in consultation with the Pastor study team, including consideration of demographic and socioeconomic data, existing emission inventories, and model simulations. The number of sites will be determined so that the concentration gradients from potential hot spots can be delineated and some of the sites will be equipped with monitors for PM and selected toxics with better temporal resolution. Potential pollutants to be measured include nitrogen oxides, PM, key toxics and other pollutants.

BENEFITS: This project is intended to collect extensive spatial and temporal data to identify hot spots of selected pollutants in Wilmington and determine the concentration gradient in the area primarily from stationary as well as mobile and area sources. The data set collected is also intended to combine with socioeconomic status data for EJ analysis and allow comparisons with previous emission inventory and dispersion modeling results. The results of this project are expected to improve our understanding of actual exposure level at an EJ community. The methodology developed from this project can be applied to other EJ communities.

COST: $400,000 (The California Energy Commission and the South Coast Air Quality Management District are considering cofunding this project.)

TITLE: Determination of the Community-Scale Spatial Variability of Ultrafine Particles

PROBLEM: Measurements of ambient ultrafine particle concentrations at a single central monitoring station may not be indicative of human exposure in the communities surrounding a single monitoring site. Due to their short atmospheric lifetimes and strong dependence on very local sources, ultrafine particle numbers vary significantly on very small spatial and temporal scales. In order to address this problem and more accurately determine human exposure and the subsequent health impacts of ultrafine particles, more intensive particle number measurements on finer spatial scales is needed.

PREVIOUS WORK: Recent studies have demonstrated that ultrafine particles are more toxic than PM10 and PM2.5. Other studies have shown that individual particles are capable of penetrating cellular membranes and causing cell damage, suggesting that particle number rather than particle mass may be more indicative of potential health effects. A previous jointly-funded ARB/AQMD study measured ultrafine particle number concentrations at each of the Children's Health Study (CHS) communities at a single central monitoring station in each community. Results showed very predictable daily and seasonal patterns. But other studies showing that ultrafine particle concentrations vary dramatically within 100 meters of roadways point out the need for more spatially resolved ultrafine monitoring within impacted communities.

OBJECTIVE: The objective is to better determine the spatial variability of ambient particle number concentrations and thus improve estimates of human exposure to ultrafine particles.

DESCRIPTION: Using 10-12 of the condensation particle counters (CPC) the intra-community variability of ultrafine number concentrations can be determined. The CPCs will be deployed at 10-12 individual sites within the cities of Wilmington and Riverside and within a 1-3 mile radius. Sampled communities will be chosen based on specific pollution characteristics and problems. Other communities will be chosen to correspond to CHS communities, allowing for comparisons to historical central site data and to CHS health outcomes. Two to three communities per year will be examined. The deployments will be accompanied by several meteorological instruments recording highly time-resolved wind speed, wind direction, humidity and temperature data. Such information can be used with the CPC continuous number data to identify local sources based on wind speed and direction. An upcoming EPA-funded project will fund this type of analysis as well as additional analyses examining the short- and long-term variations of highly time resolved number concentration data using techniques similar to Fourier transform analysis.

BENEFITS: Better information on the local-scale variability and sources of ultrafine particles will improve our understanding of human exposure to and the health impacts of this unregulated pollutant. Such information will lead to more effective control measures and/or ultrafine particle standards that will reduce the public health risk.

COST: $450,000

TITLE: Mobile Monitoring of Ultrafine Particulate Matter and Related Co-Pollutants in Community, Near-Roadway, and Roadway Locations

PROBLEM: Ultrafine particulate matter (PM) is potentially the most harmful component of particulate air pollution, but exposure data are lacking. Measurements near freeways have shown sharp concentration gradients, making fixed-site monitoring of limited value for ultrafine PM. Spatially resolved exposure data is needed to evaluate the health impacts of ultrafine PM.

PREVIOUS WORK: Animal exposure studies have found lung damage from ultrafine PM and human studies have found that ultrafine PM directly enters the bloodstream. Monitoring studies have found high concentrations and sharp gradients near roads and freeways. A pilot study that used the Mobile Monitoring Platform (MMP) concept extended this work by outfitting an electric vehicle for similar field measurements. Ultrafine PM concentrations and size data, along with gaseous co-pollutants, were measured on roadways, in neighborhoods, and near Los Angeles International airport. Ultrafine PM concentrations on roadways were one to two orders of magnitude higher than most microenvironments, making in-vehicle time the route of most ultrafine PM exposure for people who commute via freeways.

OBJECTIVE: The objective is to extend the MMP approach to more fully characterize in-vehicle, near-freeway, near-arterial, and community gradients of ultrafine PM as well as co-pollutant concentrations. These data will then be used in estimates of ultrafine PM exposure in these important microenvironments.

DESCRIPTION: The MMP approach to measuring ultrafine PM and other high-gradient pollutants will be based on an electric vehicle platform with extensive instrumentation. Enhancements to the previous MMP capabilities will include improved, rapid-response ultrafine PM instrumentation with higher dynamic range and a portable gas chromatograph to measure volatile organic compounds. Measurements will focus on high- and low-diesel traffic freeways, high and low-volume arterial roads, and characterizing the effects of meteorology on impacts to downwind communities.

BENEFITS: The findings of this study will allow better estimates of ultrafine PM exposure for Californians to ultrafine PM and other combustion-related pollutants. A better understanding of freeways and community-level concentration gradients will be gained, as well as the differences in impacts from truck traffic versus gasoline-powered vehicle traffic.

This new approach to monitoring also offers a versatile means to address questions that arise regarding the impacts of sources and exposures. For example, measurements will provide valuable baselines from which to judge the impacts of expansions at the Long Beach port and increased Mexican truck traffic, as well as the effect of reductions in diesel truck fleet emissions as the 2007 standards begin to take effect.

COST: $300,000

TITLE: Assessment of the Health Impacts of Particulate Matter from Indoor Sources: **Development of *in vitro* Metholodogy**

PROBLEM: Ambient particulate matter (PM) levels in California have been estimated to result in thousands of excess premature deaths and serious adverse impacts such as bronchitis and asthma requiring emergency room visits and hospitalizations. Indoor sources of particles, such as smoking, cooking, burning candles and incense, woodburning, and dust resuspension, are only indirectly accounted for in ambient PM epidemiology studies. PM from indoor sources such as combustion appliances and products are comprised of a variety of components known to be very toxic, and can result in elevated indoor PM mass concentrations. Consequently, PM of indoor origin may cause additional impacts not quantified in outdoor PM epidemiology studies, and/or may account for a portion of the adverse effects quantified in the epidemiology studies. In either case, such impacts are likely to be large and would require key indoor sources to be addressed in order to most effectively reduce PM exposure and risk.

PREVIOUS WORK: In February 2004, ARB convened a panel of experts to identify what is known regarding the health impacts of indoor PM. Only a few studies have estimated the relative contributions of PM from indoor and outdoor sources to the indoor PM mix. Results have been highly variable, but some of those studies have shown that a substantial portion of indoor PM in some homes is emitted from indoor sources. Only one study to date has directly examined the relative toxicity of indoor and outdoor PM; indoor PM showed greater toxicity than outdoor PM, although some weaknesses in the study limit confidence in these results.

OBJECTIVE: The objective is to identify and quantify the impacts of PM of indoor origin on human health.

DESCRIPTION: Oxidative assay type studies or similar laboratory approaches in which PM from indoor sources is assessed for its impacts on human or animal cellular activity and response will be performed.

BENEFITS: Results from this projects would begin to provide insight regarding the type and extent of impacts of indoor PM sources on health. The initial question addressed would be whether impacts comparable to those indicted with outdoor PM are seen in laboratory studies using indoor-generated PM. Ultimately, results may identify whether new epidemiology studies are needed and enable risk reduction approaches to focus on the sources most responsible for PM impacts.

COST: $400,000

TITLE: Effects of Inhaled Fine and Ultrafine Particles on Lung Growth and Lung Disease

PROBLEM: One of the most provocative and potentially important of the outcomes of the Children's Health Study (CHS), conducted by the University of Southern California, for the ARB, was the finding of reduced lung function growth associated with exposures to NO_2, acid vapor, fine ambient particles and elemental carbon (Gauderman et al., 2004 *N Engl J Med*. 351:1057-1067). Pulmonary deficits, measured as the percent of children with clinically significant depression (i.e. <80 percent of age adjusted expected level) of forced expiratory volume at one second ($FEV_{1.0}$), increased with increasing community pollutant concentration levels. The children were followed to 18 years of age, by which age, most lung growth is complete. One can therefore speculate that any deficits might not be repaired after that time. Because the pollutants in ambient air that were associated with the development of lung function deficits were intercorrelated, it is not possible to definitively attribute the health effects to one or more causal agents. It is also not known whether these deficits will manifest in chronic health effects in adult life.

PREVIOUS WORK: The effects of exposures to concentrated fine and ultrafine aerosols in several communities using mice that were sensitized to chicken egg albumin, OVA (Kleinman et al., 2005 JAWMA in Press) and acute changes in cardiac physiology in geriatric rats have been examined. To perform these studies, a portable particle concentrator (VACES) was installed in a customized van and coupled to an exposure system to allow us to study health effects and physical and chemical properties of particles in close proximity to source and receptor sites. Mice exposed to concentrated ambient particles exhibited elevations of cytokines and OVA-specific immunoglobulin, which are biomarkers of airway allergies. Mice exposed to purified air did not have significant elevations of these biomarkers. In vitro assays determined that concentrated ambient ultrafine particles induce the production of free radicals in a dose-responsive manner and that these particles were taken up by macrophage cells, accumulated in the cells mitochondria, elicited antioxidant defense mechanisms at moderate doses but caused mitochondrial disruption and cell death at high concentrations.

OBJECTIVE: The objective of this proposed study is to test the hypothesis that chronic PM exposures will cause pulmonary function deficits in rodents exposed from birth to adulthood. The hypothesis that these deficits will persist after exposures are terminated will be examined. Analyses of lungs to determine whether pulmonary function deficits are associated with pathological changes in lung structure and whether these changes are dependent on dose will also be performed.

DESCRIPTION: Repeated inhalation studies will be conducted using the VACES in two or more communities and using two concentrations of concentrated fine and ultrafine particles at each site. The low concentration will be proportional to the average concentration at the CHS community location that had the lowest level of pulmonary function deficit. The high concentration will be proportional to the concentration at the CHS site with the greatest degree of pulmonary function deficit. We will dilute the concentrated aerosol with purified air as necessary, to match the concentrations at the two sites. The concentrator will also effectively reduce the concentrations of gaseous co-pollutants (CO, NO_X). Acute and chronic cardiopulmonary inflammation and injury will be examined using transgenic mice with specific knockouts or knockins along the NFkB and NRf2 signaling pathways to test specific mechanistic hypotheses regarding the roles of inflammation and oxidative stress in the development of pulmonary and cardiovascular injury and address the question of whether

the differences in adverse human responses were due to particle dose or to qualitative differences in particle composition. Endpoints will include markers of inflammation, histological examinations for evidence of pathology and pulmonary function measurements. The physical and chemical composition of the particles will be determined and collected particles will be tested in vitro for the potential of these particles to produce free radicals and induce cytotoxicity, and heart muscle cell hypertrophy. These experiments will be conducted over a period of three years. Although mice continue to grow throughout their lives, overall growth is very slow after seven weeks of age and there is a marked decrease in the rate of lung growth with age. Thus, the rodent model is a reasonable choice for such studies.

BENEFITS: This study would provide needed information on the effects from long-term exposures to PM on lung development and function. These data will be relevant to ARB's mission to protect children's health.

COST: $450,000

TITLE: Health Effects of Short-Term Particulate Exposures

PROBLEM: California and federal ambient air quality standards have been set for annual and 24-hour averaging periods for particulate matter (PM). However, ambient PM concentrations vary by large factors, often by an order of magnitude over hourly timeframes. These brief excursions may be especially harmful as suggested by cardiac and respiratory outcomes associated with ambient PM. Little relevant health evidence exists to establish health advisories or air standards for short-term fluctuations in PM.

PREVIOUS WORK: Considerable research on the effects of particulate matter has been performed by epidemiologists who employ 24-hour metrics of pollutant concentrations collected at routine air quality monitoring sites. These scientists report associations between PM and cardiovascular and respiratory health outcomes. Some studies have examined shorter-term effects. Los Amigos Research Institute employed two-hour exposures of concentrated ambient particles in human clinical studies and observed changes in the electrical activity of the heart and biochemical markers of inflammation. Researchers at the University of California, Irvine found lung function in asthmatic children varied with one and eight-hour ambient PM levels. Studies of cardiovascular events performed by Peters et. al., in Massachusetts found that hospital admissions followed PM exposures experienced in the hours just prior to the event. In studies conducted at the University of California, San Francisco with mildly asthmatic subjects exposed for ½-hour periods to smoke from rice straw combustion, minor lung function effects were identified.

OBJECTIVE: The objective is to determine the human health impacts of brief (one to eight-hour) exposures to ambient PM in California.

DESCRIPTION: Several experimental approaches may be considered to address this issue including: panel, controlled human exposure, or statistical studies. Panel studies could be conducted with people who are likely to suffer from exposures. To increase efficiency and control costs, links to existing cohort/air monitoring projects will be considered. Personal air monitoring could refine personal PM exposures and micro-environmental exposures. Multiple health outcomes could be studied including: cardiovascular or respiratory outcomes (e.g., heart rate variability, markers of inflammation, lung function, and asthma medication use). Alternate expressions of dose may be employed in statistical analysis. Controlled exposure studies could investigate the nature of dose and dose rate on health outcomes, for example, exposures of an equal dose could be provided over one, two or 8-hours followed by health outcome measures. Statistical studies of effects could include admissions to the hospital for asthma, respiratory illness, stroke, or heart attack with time-resolved data from ambient monitors. Access to health records that contain highly-resolved time information is critical.

BENEFITS: This study would provide critical information on the health effects from short-term exposures to PM. Since PM, as with all pollutants, varies on sub 24-hour time frames, knowledge of the time frame, concentrations, and corresponding health effects of this pollutant are critical to ARB's mission to protect public health.

COST: $600,000

TITLE: Responses to Short-term Fluctuation in Particulate Air Pollution in Asthmatic Children: Implications for Asthma Natural History

PROBLEM: Children with asthma have been repeatedly identified as a "susceptible" sub-group with respect to air pollution-related health effects. The effects of chronic exposure to ambient air pollutants on the long-term outcomes of children with asthma are largely unknown in terms of overall pollutant mixture as well as particular components or properties of the gas/particle mixture that may be of greater importance. Such information is needed both for scientific reasons (better understanding of possible mechanisms and estimation of risk) and for regulatory policy. The extensive body of data on effects of short-term exposure to air pollutants on indices of asthma morbidity has been of limited value, both quantitatively and qualitatively, with respect to effects of more longer-term exposure.

PREVIOUS WORK: Through the Fresno Asthmatic Children's Environment Study (FACES), the ARB funded the creation of a cohort of children with asthma ages 6-11 who reside in Fresno, CA. Recruitment began in September 2000. Extensive exposure information on a wide variety of ambient pollutants and bioaerosols in the indoor and outdoor environments of the children are available. A substantial amount of analyses have been carried out with conventional and causal statistical procedures. The FACES investigators have submitted an application for a grant for an additional 5-years of funding (fieldwork, 3-years; analysis and publication, 2-years) through the Division of Lung Disease, National Heart, Lung and Blood Institute (NHLBI). The NHLBI grant will allow additional follow-up of the cohort to investigate further long-term exposure effects.

OBJECTIVE: The objectives are to: 1) continue FACES field data collection for an additional 12 months, which will bridge the gap to the proposed NHLBI study if the study is not funded until July 2006, and 2) conduct innovative, enhanced statistical analyses as well as additional conventional statistical analyses of longer-term respiratory health effects using robust sample sizes available with the additional data collection.

DESCRIPTION: The requested funds would be used to carry on the basic fieldwork and maintain and enhance the analysis work begun during FACES. This additional follow-up and analyses will exponentially improve the ability to detect effects in longitudinal studies through additional data collection and the addition of enhanced statistical models. The investigators will conduct robust analyses of longer-term respiratory health effects with conventional and with new and innovative marginal structural statistical models. The additional year of health and exposure data and the use of advanced modeling techniques will result in additional insights on the long-term effects in this sensitive population.

BENEFITS: FACES has the potential to provide vital information on the effects of air pollution on asthmatic children, a sensitive population. This proposal will complement the original FACES investigation by additional data collection and innovative analysis techniques resulting in more information on the long-term health impacts of air pollution in asthmatic children. The proposal will also provide funds to maintain this valuable cohort.

COST: $350,000

TITLE: Mechanisms of Cardiopulmonary Injury Caused by Mobile Source-Generated Fine and Ultrafine Particles

PROBLEM: There are strong associations between exposures to motor vehicle-derived particles and cardiopulmonary morbidity and mortality but there have been few studies that realistically examined possible differences in the effects of gasoline versus diesel-powered engine emissions. The Caldecott Tunnel, which has segregated traffic patterns, offers an opportunity to test the hypothesis that the health effects of diesel particles can be differentiated from those of gasoline particles with real world particles. Bore 1 is used by a mix of light-duty (LDV) and heavy-duty vehicles (HDV) while bore 2 is almost exclusively (99.8 percent) LDV (Gross, et al., Atmos. Sci. and Tech. 32: 152-163, 2000).

PREVIOUS WORK: Exposures to fine and ultrafine aerosols from diesel exhaust were shown to elicit allergic responses in chicken egg albumin-sensitized mice. This model was applied to determine whether exposures to freshly emitted particles from motor vehicle exhaust would also elicit airway allergies. A portable particle concentrator (VACES) concentrated fine and ultrafine particles drawn from air 50 and 150 meters from the edge of a heavily trafficked freeway system in Los Angeles and these particles were used to expose sensitized mice. Mice exposed 50 meters from the freeway exhibited elevations of cytokines and albumin-specific immunoglobulin, which are biomarkers associated with allergy-related changes in their airways. Mice exposed to purified air or concentrated particles 150 meters from the freeway did not have significant elevations of these biomarkers (Kleinman et al., JAWMA, in press, 2005). These particles were also shown to affect cardiac function and induce arrhythmias in rats.

OBJECTIVE: The objective is to test the hypothesis that there are mechanistic and outcome differences in the manner in which particles from LDV (mostly gasoline powered) elicit effects on health compared to HDV particles. Both vehicle types produce ultrafine particles that are capable of inducing pulmonary inflammation, however the HDVs emit about 50 times more particles than LDVs and the composition is not the same especially with respect to metals and reactive organic constituents. The toxicity of the fine and ultrafine particles in Bores 1 and 2 of the Caldecott Tunnel will be examined to test the hypothesis that inflammatory, cytotoxic and allergic responses will be elicited to a greater degree by HDV-derived particles, compared to LDV-derived particles, and that the acidity, reactive organic species content and metal content of the particles will influence the mechanisms of action and degree of toxicity in a dose-dependent fashion.

DESCRIPTION: Repeated inhalation studies will be conducted in the mixing plenum above Bores 1 and 2 of the Caldecott Tunnel. VACES will be used to provide adequate and matched concentrations of particles from the tunnel tubes. The concentrator will also effectively reduce the concentrations of gaseous co-pollutants (CO, NO_X). Acute and chronic cardiopulmonary inflammation and injury will be examined using transgenic mice with specific knockouts or knockins along the NFkB and NRf2 signaling pathways to test specific mechanistic hypotheses regarding the roles of inflammation and oxidative stress in the development of pulmonary and cardiovascular injury. Endpoints will include measurements of cytokines and chemokines, signal transduction mediators and histopathology. Samples to evaluate the physical and chemical composition of the particles will be collected during exposure and analyzed subsequently. In vitro tests will be performed to examine the

potential of these particles to produce free radicals and to elicit cytotoxicity and heart muscle cell hypertrophy using well characterized cell systems.

BENEFITS: This study would provide critical information on the health effects from exposures to mobile source-derived PM using real-world aerosols. Knowledge of how differences between HDV and LDV-derived PM with respect to toxicity and corresponding health effects are critical to ARB's mission to protect public health.

COST: $450,000

TITLE: Life-Cycle Cost Analysis of Air Pollution Control Regulations

PROBLEM: Life-cycle analysis is used to determine the costs of a policy option or technology choice over the entire expected lifetime of the technology or strategy. A life-cycle analysis of a vehicle technology, for example, should encompass the purchase price, fuel use, maintenance, learning curve, scrapping costs, environmental costs, congestion costs, etc., aggregated in present discounted value terms over the typical life of a vehicle. The results of this analysis usually are key inputs into subsequent analysis, from financial evaluation to regional impact models. At the core of this analysis are the assumptions (e.g., discount rate, fuel cost, etc.) used to compare costs among policy alternatives. An accurate ranking of policy alternatives provide decision-makers useful information on the selection of the alternative that has the lowest cost. The lack of consensus on assumptions unfortunately acts to limit the life-cycle analysis. It is, thus, important to achieve a consensus among competing stakeholders as to the assumptions, methodologies, and data that should be used to compare various alternatives to a policy action. The development of a user-friendly model (spreadsheet) that is able to calculate the life-cycle benefit and cost values of alternative policy actions using the most commonly used or agreed-upon assumptions would be extremely useful.

PREVIOUS WORK: There are numerous studies of life-cycle analysis. Some relevant examples are the 1990 ARB cost-effectiveness guidance, the Cal/EPA guide for reviewing environmental policy studies, and the Cal/EPA guidelines for evaluating alternatives to proposed major regulations. However, the ARB lacks a model that can be used uniformly to calculate the life-cycle benefit and cost values of all proposed regulations.

OBJECTIVE: The objective is to develop a user-friendly model that is based on the most commonly used or agreed-upon assumptions, that can utilize readily available information regarding a technology, that can perform life-cycle analysis of policy alternatives, and that can provide a summary of the economic valuations.

DESCRIPTION: A thorough literature review will be conducted to identify key assumptions used in the life-cycle cost analysis of a technology and to estimate the appropriate range and a best estimate for each assumption. A user-friendly model for the life-cycle analysis using the most commonly used assumptions in the literatures will be developed as well as guideline on how the range for each assumption used in the model should be updated.

BENEFITS: The results of this study will help ARB's regulatory development efforts. The regulatory costs and impacts will be estimated in a consistent manner and based on a full life-cycle cost and information. The staff's cost estimates would be comprehensive, robust, and less susceptible to criticisms.

COST: $60,000

TITLE: Follow-on Development of CARBITS

PROBLEM: ARB anticipates that consumer response will be an important issue in future regulations affecting passenger vehicles. Automobile manufacturers and their consultants raised this issue during development of the Zero Emission Vehicle (ZEV) regulation and the climate change regulation. So it is worthwhile to continue to upgrade CARBITS, ARB's in-house model of consumer response in the passenger vehicle market.

PREVIOUS WORK: ARB contracted with Professor David Bunch of the University of California, Davis for the development of CARBITS. ARB used CARBITS in support of the climate change regulation adopted by the Board in September 2004. Time and money ran out before completing all the desired features of the model. Also the experience of using the model gave rise to ideas for improving it. CARBITS was sufficient for the supplemental analysis included in the staff report. However, additional enhancements will increase its utility for other major motor vehicle regulations.

OBJECTIVE: The objective of this project is to upgrade CARBITS, to improve ARB's in-house ability to model consumer response in the passenger vehicle market.

DESCRIPTION: This project will enhance CARBITS by incorporating the following features:

- Use more recent survey data
- Include hybrid vehicles
- Incorporate a scrappage sub-model
- Calculate consumer surplus
- Allow flexibility in user-selected start year for regulation scenarios to cut run time nearly in half
- Recalibrate to take into account consumer perceptions of environmental attribute of vehicles
- Reduce or eliminate statistical noise.

BENEFITS: This project will enhance ARB's in-house ability to model consumer response in the passenger vehicle market. ARB is gradually improving the sophistication of its economic analysis. The next logical step is for ARB to continue to improve CARBITS, which has received a great deal of attention from consultants of the automobile manufacturers. CARBITS will be important for analyzing future proposed regulations that have a large impact on passenger vehicle price or attributes.

COST: $100,000

TITLE: The Economic Value of Avoiding Lifelong, Air Pollution Exposure-Related Health Outcomes

PROBLEM: Epidemiological studies have linked particulate matter and ozone to a variety of chronic or lifelong adverse health outcomes. These include, but are not limited to, asthma, permanently reduced lung function and pre-term birth. Regulation of air pollutants would result in reduced incidence of these outcomes. But it is impossible to determine the economic benefits of such regulation without estimating both the number of such cases caused by air pollution in California, and their costs.

PREVIOUS WORK: ARB's 2004 Children's Health Study demonstrated an association between air pollution and asthma as well as other health outcomes including lung function deficit. Professor Beate Ritz of the University of California, Los Angeles, has shown an association between air pollution and pre-term birth among children born in southern California. A 2003 ARB-funded study estimated the economic benefits of reducing respiratory and cardiovascular hospitalizations by combining cost-of-illness (COI) and willingness-to-pay (WTP) findings.

OBJECTIVE: This study's objective is to identify, quantify, and value chronic/lifelong, air pollution-linked health outcomes that have not been fully valued.

DESCRIPTION: A literature review will be performed to assess relevant dose-response functions, quantification studies, and economic evaluation studies. An interim report will present the results of this review, highlighting the highest-cost health outcomes for California with adequately documented dose-response ratios. With ARB's guidance, California-specific exposure data will be assembled and quantified to the baseline incidence rates of selected chronic/lifelong health outcomes. In cooperation with one or more health insurance and/or health service providers that treat large numbers of patients in California, representative COI and WTP data including socioeconomic factors such as environmental justice considerations will be collected and analyzed. Results will be integrated with previous findings on hospitalization and premature death to comprehensively evaluate the direct and indirect benefits of regulations that reduce the incidence or severity of asthma and other selected disorders due to reduced exposure to air pollution.

BENEFIT: The study will extend both empirical and methodological bases for economic benefit valuation of air quality control measures. It will provide a more complete, accurate, and up-to-date health benefit estimation, increasing the ARB's ability to assess the benefits of reducing particulate and ozone exposure.

COST: $250,000

TITLE: Quantitative Assessment of Health Benefits of Improvements in Air Quality in Southern California

PROBLEM: Dramatic improvements in ambient air quality have occurred in southern California over the last 25 years; however, very little quantitative information is available with regard to the actual health benefits associated with the air quality improvements. The overall health benefits and disease-specific benefits that can or cannot be ascribed to these improvements have not been subject to rigorous quantitative analysis or economic valuation.

PREVIOUS WORK: A pilot study by the University of California, Berkeley that brings together a 21-year history (1980-2000) of air quality data from the South Coast Air Basin and the spatially relevant hospital discharge and mortality data. Investigators mapped pollutant concentrations for 50 subregions that are coherent in terms of homogeneity of pollutants and demographics and identified all hospital discharges and deaths from each unit from 1980-2000. They developed and have begun to test the application of causal modeling to these data. Preliminary analyses on the effect of ozone exposure on hospital admissions for asthma have been conducted and will be completed by the end of the pilot study.

OBJECTIVE: The objectives are to: 1) carryout a definitive analysis to quantitate additional relationships between long-term changes in air pollution on human health; specifically an asthma discharge analysis for PM2.5 and a mortality analysis for ozone and PM2.5; 2) carryout parallel analyses that value these benefits in economic terms; and; 3) expand the current database to include air pollution, hospitalization, mortality and demographic data through 2004 to provide the most contemporary assessment possible.

DESCRIPTION: Air pollution, hospital discharge, mortality and demographic data will be mapped to the previously established spatial units. Advanced methods of causal analysis will be applied to estimate health effects that account for the multi-pollutant environmental, the entire history of air pollution changes over the years 1980-2004, and changing temporal demographic patterns that could confound results. An economic valuation will be conducted that uses methods based on hedonics and contingent valuation (CV) that includes the emerging CV literature on valuation of adverse health impacts in children and the elderly. These analyses can be supported by age and cause-specific hospital discharge and mortality data, which accounts for underlying conditions.

BENEFITS: The analyses from this project will provide global population-based estimates of health effects related to long-term reduction in air pollution and their resultant cost that cannot be derived from the extant health effects database. Such data are valuable to regulators and health policy analysts. These methods can be extended to cover other large population areas in the state to enhance the scope of the analysis database upon which regulators and health policy analysts can draw upon for decision making.

COST: $200,000

TITLE: Effects of Sound Walls and Tree Lines on Concentrations of Particulate Pollutants Above and Adjacent to Freeways in Residential Neighborhoods

PROBLEM: Sound walls and tree lines are often requested by communities as a way to reduce concentrations of particulate matter at neighborhood sites near freeways. However, data are not available to determine the effect of sound walls or tree lines under modern conditions or dispersion of particulate matter into nearby residential neighborhoods, or the effect of sound walls or tree lines on particulate concentrations immediately above the freeway. Data collected could be used to characterize and reduce community exposure to air pollutants. A research project could partially address how emissions are dispersed and transported in the atmosphere and how physical structures such as sound walls affect pollutant dispersion and transport.

PREVIOUS WORK: In 1984, Caltrans studied carbon monoxide concentrations in neighborhoods adjacent to sound barriers. Carbon monoxide is a gas and would disperse differently than particulate matter that is subject to deposition. In addition, modern sound walls in general have become taller (14-16 feet high rather than 8-12 feet) since the 1984 study.

OBJECTIVE: The objective is to conduct experiments to determine how particulate matter disperses in the presence of sound walls and tree lines, as compared to control sites without sound walls or tree lines. Issues of interest include whether and to what degree particulate matter concentrates within the confines of sound walls and tree lines, thereby increasing exposure for vehicle occupants, how sound walls or tree lines may affect particulate matter concentrations and deposition in neighborhoods adjacent to freeways, and appropriate methods for modeling these effects using commonly available tools.

DESCRIPTION: Particulate Matter (PM) mass and size sampling will be conducted immediately above and alongside freeways with and without sound walls, and with and without tree lines. PM sampling will also be conducted at breathing levels at increasing distances from freeways. Compare results with modeling using common microscale dispersion models such as Caline4, and appropriate methods will be suggested for use of such models to predict particulate matter concentrations in the presence of sound walls or tree lines consistent with the results of monitoring.

BENEFITS: If sound walls or tree lines significantly reduce particulate matter, especially diesel exhaust particulate concentrations in neighborhoods or at school sites near major freeways, they could be considered as mitigation measures. If sound walls or tree lines significantly increase concentrations at roadway levels within the confines of the walls, particulate matter exposure to motorists may be increased. Developing and validating appropriate modeling methods would assist with determining the optimal size and configuration of sound walls or tree lines with respect to effects on particulate matter concentrations.

COST: $150,000

TITLE: Impact of Reactive Halogen Gases on Air Quality in California Coastal Areas

PROBLEM: Hydroxyl radical (OH) is widely considered the dominant daytime oxidizing species, initiating ozone chemical formation in the presence of VOCs and NO_X. However, there is increasing evidence that halogen atoms, specifically chlorine and bromine, also are significant oxidants in coastal areas. Reactive halogen gases (Cl_2, BrCl, Br_2) are produced from chemical reactions on sea salt particles and readily photolyze in the early morning to produce halogen atoms. Cl-atoms oxidize hydrocarbons 100 times faster than OH, thus initiating ozone production and aerosol formation earlier than possible from OH chemistry alone. For these reasons, it is suspected that this accelerated chemistry can lead to higher daytime ozone concentrations, affect aerosol particle formation and composition, and potentially increase human exposure in highly populated coastal cites of California. Conversely, Br-atoms do not react rapidly with most organics, but do react with ozone and lead to its destruction. Regional photochemical models used to evaluate the effectiveness of emission control strategies in ozone non-attainment areas do not account for halogen reactions and therefore may be seriously flawed when applied to coastal regions. Measurements of reactive halogen gases in coastal areas are needed to assess their potential importance and to determine if halogen chemistry should be included in air quality models.

PREVIOUS WORK: Direct measurements of up to 150 pptv Cl_2 on the Long Island, NY, coast and indirect measurements of up to 127 pptv Cl_2 on the Florida coast have been made. Direct measurements of up to 27 pptv Br_2 and 35 pptv BrCl have been made in the Arctic prior to polar sunrise. Laboratory studies have established that Cl_2 is likely present in on-shore marine airflow due to reactions involving sea-salt particles, which are ubiquitous in California coastal regions. Modeling studies of Southern California have shown that including chlorine chemistry increases ozone levels by as much as 12 ppb over a base case at Long Beach. However, chlorine and bromine effects on California photochemical air pollution cannot be truly assessed until measurements of these gases are made.

OBJECTIVE: The objective is to measure reactive halogen gases and associated pollutants at a Southern California coastal site and to assess the potential significance of reactive halogen chemistry on California air quality.

DESCRIPTION: A two-week summertime field measurement campaign will occur during Year 1 in the Los Angeles area. The gases Cl_2, BrCl, and Br_2 will be measured on-line by atmospheric pressure chemical ionization mass spectrometry to quantify their diurnal variation. Differential optical absorption spectroscopy will be used to measure halogen oxide concentrations, as well as ozone, NO_2, and HCHO. On-line size resolved aerosol composition measurements will be made to characterize the urban/marine aerosol and the evolution of its composition (SO_4, NH_4, NO_3, Cl, Br, Na, K, organics). In Year 2 these data will be used in an appropriate gas-aerosol model to analyze the impacts of measured halogen gases on urban air ozone and aldehyde concentrations, and on aerosol composition and size distributions.

BENEFITS: The results will be an improved understanding of coastal urban air chemistry. This knowledge is needed to assess emission controls for reducing ozone concentrations.

COST: $300,000 (The South Coast Air Quality Management District is considering cofunding this project)

TITLE: **Secondary Organic Aerosol Formation for Volatile Organic Compound Mixtures at Varying VOC/NO_X Ratios**

PROBLEM: Secondary organic aerosol (SOA) formed in the atmospheric reactions of volatile organic compounds (VOCs) in the presence of oxides of nitrogen (NO_X) constitutes an important component of suspended fine atmospheric particulate matter (PM) that impacts visibility, climate, and health, especially during summertime. The chemical compositions of SOA are not well identified, and the semi-empirical models have been used to predict the formation of SOA from anthropogenic and biogenic VOCs. As a mixture, SOA is predicted to depend on reactant concentrations, temperature, humidity, and the nature of the background PM, but current environmental chamber data to test predictions of these dependences are limited and do not represent ambient conditions. The dependence of SOA on other reactive species and reactive organic gases (ROG) and NO_X levels may be significant but have not been determined. Such data as well as speciated SOA compositions may significantly improve the accuracy of model predictions of fine PM.

PREVIOUS WORK: SOA formation is typically modeled using gas/particle partitioning theory coupled with semi-empirical models with parameters based on environmental chamber experiments carried out using much higher than ambient concentrations, and usually with simple chemical systems such as single organic – NO_X. The new University of California, Riverside/US Environmental Protection Agency (UCR/EPA) chamber, which was developed to conduct well-characterized model evaluation experiments at lower reactant concentrations than possible previously, has been demonstrated to have utility for SOA research and results from this chamber are already available. Further work on the interaction of m-xylene and NO_X at low organic aerosol loading demonstrates that the relative concentrations of each species play a significant role in the secondary organic aerosol formation potential of m-xylene in the atmosphere. Furthermore, initial tests on mixtures of toluene and m-xylene did not produce the expected SOA formation potential as predicted by their individual species.

OBJECTIVE: The objective is to determine the SOA concentrations and compositions from selected aromatic compounds under a range of conditions in the ambient concentrations.

DESCRIPTION: Experiments will be carried out in the UCR/EPA chamber to determine the SOA concentrations and compositions from selected aromatic compounds under a range of conditions in the ambient concentration range. The conditions will include VOC and NO_X levels, the presence of other reactive VOCs, and temperature. The experiments will be carried out with the high level of characterization used for gas phase mechanism evaluation. The results will be analyzed not only in terms of predictions of current and newly developing theories and models for SOA formation, but also in terms of model simulations of the gas phase processes occurring in the experiments. Such model predictions will be used as a tool in designing the most useful experiments to carry out.

BENEFITS: Data on SOA formation in well-characterized experiments representing a range of atmospheric conditions are essential to test and improve our theories and models for predicting SOA in the atmosphere. Since SOA can exceed 70 percent of the fine particulate burden on highly impacted days in summer, accurately predicting its formation is essential to developing cost-effective control strategies for fine PM.

COST: $225,000

TITLE: Process-Based Farm Emission Model to Estimate Air Emissions from California Dairies

PROBLEM: Accurate estimation of the emission rates of various pollutants from dairies, which are one of the major sources for air pollutants in the state, is important for both regulatory agencies and dairy farmers. The current approach of regulatory agencies uses annually based emission factors. It does not take into account the temporal and spatial variation of emissions that occur on actual farms due to variation of animal housing and manure management practices and changes of meteorological conditions. For the air pollutants that impact local and regional air quality, such as ammonia (NH_3), hydrogen sulfide (H_2S) and volatile organic compounds (VOCs), the annual emission factors have very limited use for analyzing the dynamic causes of poor air quality and finding solutions for mitigating the emissions. Hourly emission rates of these gases from dairies are needed to assess their contributions to the dynamics of air quality that occurs in different parts of the state and different times of the year so that specific emission control strategies can be effectively developed.

PREVIOUS WORK: A project at the University of California, Davis has been developing a process based ammonia emission model for livestock farms under the sponsorship of Lake Michigan Air Directors Consortium (LADCO). A first version of the model is expected in spring, 2005. However, there is a lack of accurate data for use as input values and for calibrating and validating the model. On the measurement side, the investigators at the campuses of the University of California, Davis and Berkeley have developed highly capable research facilities (environmental chambers for cow housing and laboratory waste treatment reactors) and measurement techniques for gaseous emissions from dairy facilities. Both of these projects will be used to support the proposed work.

OBJECTIVE: The objective is to develop a process-based dairy farm emission model for NH_3, H_2S, and VOCs, which could be used to estimate and predict the emission rates of these gaseous compounds at different temporal and spatial scales.

DESCRIPTION: The process-based approach, recently recommended by National Academy of Sciences (NRC 2003), will be used to analyze all the emission sources (animal feeding, housing, manure storage and land application) on dairies and develop a comprehensive farm-based emission model for NH_3, H_2S, and VOCs. For ammonia, the models that have been developed for LADCO project will be used. Controlled experiments will be conducted to collect data on their emission rates from different sources on dairies. After the completion of emission models, sensitivity analyses will be performed for all the parameters involved in the models to identify the most important ones and develop recommendations for emission mitigation strategies.

BENEFITS: The process-based emission model will provide the air quality regulatory agencies, scientific community, and dairy industry with the capabilities to estimate the emission rates of primary air pollutants and develop effective emission mitigation strategies for air quality improvement.

COST: $300,000

TITLE: Measuring Agricultural Fumigant Pesticide Emissions through In-Field Testing

PROBLEM: Fumigant pesticides are the largest contributors to the pesticide volatile organic compound (VOC) inventory. Under current assumptions, nearly 100 percent of the VOC emissions from fumigants are thought to be released to the atmosphere. Although there is ongoing work to obtain in-field measurements, additional research is needed to validate and expand on the work that is currently being done.

PREVIOUS WORK: In fiscal year 2004-2005, Dr. Scott Yates of the University of California, Riverside was granted a contract by ARB to look at different methods to reduce fumigant pesticide emissions. Dr. Yates will conduct a series of field experiments that are designed to estimate the emissions and potential VOC reductions for three fumigant pesticides that are most commonly used in California: metam sodium, 1,3-dichloropropene (1,3-D), and chloropicrin. The purpose of the experiments is to determine emissions estimates based on different application techniques including (a) broadcast shank fumigation with and without intermittent water seals, (b) shank fumigation comparing surface packing with an intermittent water seal, and (c) broadcast-shank fumigation with and without a surface treatment. Each of the experiments will be conducted on 5-acre fields in the San Joaquin Valley. Due to the high cost of in-field research, a limited number of parameters are included in this research. Therefore, additional work is needed to consider other parameters that may also reduce fumigant pesticide emissions.

OBJECTIVE: The objective is to conduct additional field research to build upon the ongoing work to estimate the emissions and potential VOC reductions from fumigant pesticides.

DESCRIPTION: Perform in-field testing on commercial agricultural fields to measure fumigant pesticide emissions. Examples of additional work may include variations in application technique, water sealing practices, mitigation measures, fumigant type, soil type, and/or geographic region.

BENEFITS: This additional research will improve the accuracy of ARB's pesticide emissions inventory. It will also benefit the development of State Implementation Plans (SIPs) and assist in identifying additional mitigation strategies.

COST: $100,000

TITLE: On-Road Measurement of Fine Particles, NO_X, and Volatile Hydrocarbons from Light- and Heavy-Duty Vehicles

PROBLEM: Motor vehicles are a significant source of hydrocarbon, oxides of nitrogen (NO_X) and fine particle emissions. The rates and relative profiles of these emissions have likely been impacted by recent changes in fuels and vehicle technologies; in particular, phase three reformulated gasoline and new diesel engine emission control technologies. Of primary concern are changes in total NO_X (and ratio of NO: NO2), total particulate matter (PM)(and organic and elemental carbon contributions), and volatile organic compounds.

PREVIOUS WORK: Quantifying emissions from motor vehicles during on-road operation is relatively rare compared to laboratory-based studies because of the increased complexity of on-road studies. Tunnel investigations have provided a reliable technique for measuring light- and heavy-duty emissions during real-world operation. The most recent effort to quantify fine particulate, NO_X and volatile hydrocarbon emissions from California light- and heavy-duty vehicles occurred in 1997 (Kirchstetter, T.W.; Harley, R.A.; Kreisberg, N.M.; Stolzenburg, M.R.; Hering, S.V. *Atmos. Environ.* **33**, 2955, 1999).

OBJECTIVE: The objective is to measure the emissions of a broad range of pollutants – fine particulate, NO_X, and volatile hydrocarbons - from both light- and heavy-duty motor vehicles during real-world operation.

DESCRIPTION: In collaboration with the Bay Area Air Quality Management District, measurement of NO, NO_2, CO, volatile hydrocarbons (speciated), fine particles (mass, elemental and organic carbon, black carbon), and CO_2 will be performed at the Caldecott Tunnel to determine emission factors for both light-duty and heavy-duty vehicles. These measurements will occur while vehicles are headed up a 4 percent grade through the tunnel, with engine loads similar to typical freeway driving. The study is planned for two sets of weeklong measurements in the summers of 2006 and 2007.

BENEFITS: This study is intended to quantify the efficacy of past efforts to control emissions of pollutants as well as provide a baseline to understand the benefits of future efforts such as ultra-low sulfur diesel fuel and diesel particulate traps. In addition, results can be used to refine motor vehicle emission inventories.

COST: $250,000

TITLE: Hourly Monitoring of Acrolein in Ambient Air and the Assessment of Short-term Exposure Risks to Acrolein in Areas Heavily Impacted by Vehicular Traffic

PROBLEM: Acrolein has been identified by the Office of Environmental Health Hazard Assessment (OEHHA) as a pollutant that can cause infants and children to be especially susceptible to illness. ARB's current method (MLD066) for measuring acrolein in ambient air provides only 24-hour measurements that cannot be used to estimate the potential acute health risks. Potential acute health risks are estimated using one-hour concentrations. Hourly measurements of acrolein concentrations in ambient air are needed to assess short-term exposure risks.

ARB staff believe that the acrolein measured in ambient air is predominately from motor vehicle exhaust. However, acrolein can also be formed in the atmosphere from chemical reactions involving various hydrocarbons, including 1,3-butadiene. The contribution of acrolein from secondary emissions due to photooxidation is unknown, but it is suspected to be significant. To better understand the potential contribution of acrolein in ambient air due to photooxidation, it is necessary to take acrolein measurements during the winter and late summer/fall at different times of the day.

PREVIOUS WORK: The Department of Environmental Toxicology, University of California, Davis measured ambient air concentrations of acrolein and other carbonyls at the Oakland-San Francisco Bay Bridge toll plaza. Four-hour measurements of acrolein and other potentially toxic carbonyls in air were sampled during rush hour traffic, which was considered a "worst-case scenario" for outdoor air carbonyls.

OBJECTIVE: The objective is to: 1) evaluate and select and an appropriate test method for measuring hourly concentrations of acrolein in ambient air; 2) the test method's level of detection must be below OEHHA's acute noncancer Reference Exposure Level for acrolein of 0.19 micrograms per cubic meter or 0.09 parts per billion; 3) acrolein concentrations will be measured hourly during winter and late summer/fall at selected sites that are heavily impacted by vehicular traffic and 4) estimate the short-term exposure risks to acrolein at the selected sites.

DESCRIPTION: In consultation with ARB staff, a reliable test method will be selected for measuring hourly concentrations of acrolein in ambient air. The placement of the 1-hour monitors will be based on current sites having the highest 24-hour measurements of acrolein in ambient air. Hourly measurements will be taken in the winter and late summer/fall to evaluate the different hourly/seasonal patterns of acrolein in ambient air. Duplicate samples will be taken for comparison. The maximum 1-hour acrolein concentrations will be used to estimate the potential acute health risks at each site.

BENEFITS: Hourly measurements of acrolein concentrations in ambient air will allow the ARB to estimate the potential acute noncancer health risk from the exposure to acrolein in communities that are impacted heavily by motor vehicle exhaust and help in determining the need to further reduce acrolein emissions. Evaluating the daily/seasonal behavior patterns of acrolein will help in understanding the contribution of acrolein due to secondary formation.

COST: $150,000

TITLE: Physicochemical and Toxicological Assessment of the Semi-Volatile and Non-Volatile Fractions of Particulate Matter from Heavy- and Light-Duty Vehicles Operating with and without Emissions Control Technologies

PROBLEM: Recent emissions testing in either dynamometer or on-road testing facilities have shown that particles emitted from vehicles are externally mixed. Depending on vehicle type, age and ambient conditions, between 70-90 percent of the particles by number and 10-30 percent by mass may consist of more volatile material than others (known as semi-volatile), and upon heating, will partially or completely evaporate (Sakurai et al., 2003). The exposure and health implications of these findings have not yet been investigated. Considering that the majority of people's exposure during their commute will be dominated (at least based on particle numbers) to these particles, it would be useful to know whether the non-volatile or semi-volatile material is more toxic.

PREVIOUS WORK: In addition to the aforementioned studies by the Southern California Particle Center and Supersite, (SCPCS), (Zhang et al., 2004) showed that that the volatility of traffic-generated particles explains the more rapid decay in their concentration with respect to distance from a roadway, compared to that of non-labile particulate matter species (such as elemental carbon) or gaseous co-pollutants such as CO and NO_X. SCPCS studies (Kuhn et al., 2004) also showed significant shrinkage of these particles as they infiltrate indoors. Yet to-date, there is no information on the relative toxicity of these particles compared to the larger, non-volatile (refractory), mostly carbonaceous fraction.

OBJECTIVE: The objective is to determine the physicochemical and toxicological properties of the semi-volatile and non-volatile fractions of PM from heavy- and light-duty vehicles operating with and without emissions control technologies

DESCRIPTION: In this project, thermal denuders will be used, in conjunction with the University of Southern California particle concentrators (VACES), to investigate the relative toxicity of PM of different volatilities emitted from heavy duty and light duty, vehicles with-without PM filter traps and catalysts, using a dynamometer. The suspension of the collected PM will be used to determine whether particles of different volatility from different experimental configurations induce mitochondrial perturbation and reactive oxygen species (ROS) generation in a variety of different cell types such as macrophages, epithelial cells, endothelial cells, neuronal cells, renal cells and hepatocytes. The methodology for these toxicological evaluations is described in recent SCPCS papers by Li et al. (2003) and Xia et al. (2004) published in *Environmental Health Perspectives.*

BENEFITS: The semi-volatile PM fraction of vehicle emissions is extremely important in terms of its contribution to human exposure. Current emission control technologies remove effectively the non-volatile fraction, but not the volatile fraction. In fact, removal of the non-volatile PM fraction has been shown to increase the concentration of the volatile fraction by enhancing nucleation of condensing organic vapors. Knowledge of how the toxicity of vehicular PM varies with particle component volatility will direct the design of emissions control technologies in order to better protect public health.

COST: $500,000 (The South Coast Air Quality Management District is considering cofunding this project.)

TITLE: Ammonia Emissions from California In-Use Light-Duty Vehicles

PROBLEM: Ammonia emitted into the atmosphere is an important contributor to ambient particulate matter (PM) as it reacts with atmospheric nitric acid to form ammonium nitrate. Light-duty, catalyst-equipped vehicles are known to emit significant concentrations of ammonia but a comprehensive inventory for this emissions category is not available. Such an inventory is needed as PM control strategies are developed.

PREVIOUS WORK: No comprehensive testing of a representative California fleet of in-use light-duty vehicles has been reported. In 1998, Cass (ES&T, 32, 1053-1057) reported results of a tunnel study which indicated that motor vehicles represent approximately 15 percent of the overall emissions inventory in the South Coast Air Basin. Investigators at College of Engineering – Center for Environmental Research and Technology (Durbin et al., Atmospheric Environment, 3, 2699-2708, 2004) recently reported on fuel sulfur effects from a 12-vehicle fleet.

OBJECTIVE: The objective is to determine ammonia emission rates from a representative fleet of light- duty vehicles tested at the Haagen-Smit Laboratory (HSL) of the Air Resources Board as part of the In-Use Vehicle Surveillance Program. One deliverable will be a database of ammonia emission rates integrated into ARB's VEDS database. A second deliverable will be a final report that analyzes in detail the emissions rate of the fleet as a function of the various parameters typically recorded in the VEDS database. This includes factors such as emissions control technology, driving cycle, fuel type and vehicle mileage. A correlation of ammonia emissions with nitrogen oxide emissions will also be obtained for the various parameters.

DESCRIPTION: ARB's In-use Vehicle Surveillance Program is designed to provide a comprehensive database of criteria pollutant emissions from a representative fleet of California light-duty vehicles. This ongoing program can be readily expanded to include the measurement of ammonia using FTIR spectroscopy. A two year collaborative agreement is sought with a local university that would bring at least one student to the HSL to work with ARB staff to carry out the FTIR measurements, reduce the data and complete a final report. A similar collaboration recently led to the timely development of an inventory for nitrous oxide emissions from light duty vehicles.

BENEFITS: Successful completion of this project will provide regulatory staff with the data they will need to develop sound control strategies for PM. In the long run this will benefit Californians by reducing their exposure to this harmful substance.

COST: $150,000

TITLE: **Ultrafine Particle Concentrations in Schoolrooms and Homes**

PROBLEM: Several studies have implicated ultrafine particles, i.e., those with diameters below about 100 nm, with adverse health effects. They have been specifically implicated in oxidative stress and as a risk factor for cardiovascular events. Yet, knowledge is limited regarding the concentration of ultrafine particles in indoor environments, especially schools and homes.

PREVIOUS WORK: The presence of ultrafine particles in indoor environments may originate from the transport of outdoor air, and from indoor generation processes. Cleaning products and air fresheners contain terpenes that may react with ozone to form ultrafine particles. Cooking is another source of ultrafine particles. Baseline data on the concentrations of ultrafine particles inside schoolrooms and homes is limited because conventional ultrafine particle counters utilize butanol, a malodorous substance. Recently a water-based condensation particle counter has been developed, and shown to efficiently count ambient and vehicular exhaust particles as small as 5 nm. This instrument allows, for the first time, the convenient monitoring of indoor ultrafine particles in occupied environments over an extended period.

OBJECTIVE: The objective is to characterize ultrafine particle concentrations in schoolrooms and homes under conditions of varying proximity to roadways, and for differences in types of activities, such as cleaning and cooking, that may serve as indoor generators of ultrafines.

DESCPRITION: Indoor and outdoor concentrations of ultrafine particles will be measured, together with indoor and outdoor ozone, carbon dioxide (CO_2) and T/RH in approximately eight schoolrooms. These will be selected to provide data near, and distant from heavily traveled roadways, and with, and without the influence of the use of cleaning substances or air fresheners that could provide a source of secondary ultrafines. A single instrument suite, with a manifold that switches between indoors and outdoors, will be utilized to establish indoor-outdoor concentration relationships. The decay of carbon dioxide once school children leave the room will be used to infer the effective air-exchange rate. Monitors on doors and windows will indicate when these are opened and closed. Data will be collected over a period of one week at each location, and will be logged with a time resolution of approximately 10 seconds. The first year will focus on data collection schools. In the second year, measurements will be extended to a comparable number of homes. A pilot study will be conducted in one school and home location prior to school and home testing to: verify acceptable accuracy and precision of the instrument in measuring ultrafines in these settings; assure minimal line losses from the toggle approach; and determine the adequacy of the proposed CO_2 decay method for providing a usable air exchange rate measurement.

BENEFITS: This project will provide a survey of ultrafine particle concentrations in schools and homes as a function of traffic proximity, indoor activity and air exchange rate. This is important baseline information that will establish a foundation of future work that could more closely examine the mechanisms of transport and indoor ultrafine formation. The work will also provide a direct empirical basis for improving estimates of inhalation exposure to ultrafine particles.

COST: $300,000

TITLE: Survey of the Use of Ozone-Generating Air Cleaners by the California Public

PROBLEM: The advertising for, and sales of, air cleaners for home use have increased substantially in recent years. Some indoor air cleaners emit ozone, either purposely (ozone generators) or as a by-product of their particle removal process (ionizers and electrostatic precipitators [ESPs]). Both ozone generators and some ionizers have been shown in chamber and test home studies to emit ozone at rates that result in unhealthful indoor concentrations, sometimes several times greater than the 1-hour California ambient air quality standard of 0.09 ppm (90 ppb) ozone. However, reliable data are not available on the actual purchase and use of ozone-generating air cleaners in California, nor is it known whether most purchasers are aware of the potential harm to health the ozone emissions may cause. Without reliable data on the extent of use of these devices by Californians, it is difficult to estimate the extent of their potential impact on public health.

PREVIOUS WORK: No study has been conducted to provide information on the population saturation of ozone-generating air cleaners. A recent report by Freedonia, an international business research company, excluded purposeful ozone generators from their study of indoor air cleaners. However, they assembled sales figures from about 80 percent of the companies that produce filter-based air cleaners, ionizers, and ESPs, and estimated recent sales of about $395 million per year nationwide, which yields an estimate of about $50 million a year in California. However, the number of air cleaners of different types sold was not reported. Freedonia estimates that the current annual average increase of 5.4 percent in sales of air cleaners will continue for the next 5 years.

OBJECTIVE: The objective is to conduct a representative survey of the California public to identify the extent of use of different types of air cleaners, especially ozone-generating models, in California homes; the reasons for their purchase; the frequency and duration of use; and other information needed to assess the potential impact of these appliances on public health and the need for further action.

DESCRIPTION: Sponsor a statewide mail or telephone survey (or combination of approaches) of the California public to determine the extent to which they have purchased and used indoor air cleaners, especially ozone-generating models. Obtain data on the type of brand and model, year purchased, frequency and duration of use, reasons for purchase and use, knowledge of function of the device and manufacturers' instructions and cautions, knowledge of alternatives, and other pertinent information.

BENEFITS: Provide information needed to assess the scope of the possible impacts of air cleaners on Californians' health and to guide future exposure and risk reduction approaches.

COST: $100,000

TITLE: Characterization of Ventilation Rates and Indoor Environmental Quality (IEQ) on Small Commercial Buildings

PROBLEM: The quality of indoor air has a significant effect on occupant health. Pollutant levels inside buildings may be two to five times higher than those outside, and people may be 1000 times more likely to be exposed to pollutants indoors than outside. This exposure results in increased asthma and other respiratory problems, and increased cancer risk. In fact, the ARB estimates that 200 cancer cases arise each year in California as a result of indoor chemical pollutants. The majority of non-industrial, non-agricultural workers in the United States work in small commercial buildings; however, very little is known about IEQ in small commercial buildings.

PREVIOUS WORK: Most published IEQ field studies in commercial buildings have been performed in buildings with a floor area greater than 5,000 m^2. Energy efficiency field studies have also concentrated on large commercial buildings. The prior focus on large buildings in IEQ studies is due in large part to the researchers' desire to obtain health symptom data from large numbers of people and to the additional administrative burdens of gaining access to multiple buildings for research purposes. It is believed by many researchers and building professionals that the quality of building systems and the qualifications of building operational personnel are far lower in the smaller commercial building stock resulting in a higher frequency of indoor environmental and energy efficiency problems.

OBJECTIVE: The objective is to quantify the effects of building characteristics, energy use and practices, and sources of indoor pollution on IEQ in California.

DESCRIPTION: This project will: 1) obtain information that can be used to better understand the sources of indoor air pollution and identify how emissions from those sources relate to energy consumption; 2) quantify the relationship between IEQ and energy use; and 3) provide guidance for improving IEQ while reducing energy consumption. Research in this project area will include surveys of: a) ventilation system types, conditions, and performance; b) operation and maintenance practices; c) pollutant sources; d) IEQ conditions (e.g., temperatures, pollutant concentrations); and, when possible, energy use in commercial buildings with a floor area less than 5,000 m^2. The project will cover a range of building designs, occupancy types, use patterns, and climate zones.

BENEFITS: Information developed in this project will provide a better understanding of the relationship between indoor IEQ and energy use and will provide guidance for achieving both improved indoor energy efficiency and improved IEQ. Results will be used in developing building standards. Data from this research will identify design features, technologies, and practices that help to maintain acceptable IEQ without degrading building energy performance. The findings should help researchers, building professionals, and policy makers identify the extent and nature of ventilation and IEQ problems in small commercial buildings and will elucidate where corrective measures should be focused.

COST: $1,600,000 (This project will be funded by the California Energy Commission.)

TITLE: Evaluation of the New European Methodology for Determination of Particle Number Emissions and its Potential in California for In-Use PM Compliance Testing

PROBLEM: The need for a robust, on-vehicle PM sampling methodology or a surrogate for determining over-the-road "real world" emissions is undisputed. A sufficiently robust and defensible set of on-vehicle measurements for particle emissions could be used to determine in-use compliance with engine emission standards if presented in consistent units. However, a suitable option has not been identified at present time.

PREVIOUS WORK: Under the auspices of the United Nations, a multi-country Particle Measurement Program (PMP) has been underway for a few years in Europe and Japan. Recognizing the limitations of the gravimetric method for PM emission determination, the PMP is focused on the identification of new and/or improved test methods for type approval (or certification as is known in the U.S.). Significant progress has been accomplished by the PMP. At present, validation of the new proposed method is underway in Europe and Japan. In addition, the PMP suggested approach has been in use for field measurements in Europe since 1998. Since 2001, the method is used for the verification of efficiency of diesel filters. The robustness and merit of the new PMP method has led to the development of a new regulation by the Swiss Agency for the Environment, Forests, and Landscape to limit the number of particles emitted by diesel-powered vehicles. This new regulatory limit would complement the existing limit on total particle mass. It is noted that there is current work in the U.S. (in California specifically) that involves the investigation of on vehicle measurement options. But none has included the specific investigation of the PMP approach.

OBJECTIVE: The objective is to conduct a critical evaluation of the proposed PMP method for determination of particle emissions and its potential in California for in-use PM compliance testing.

DESCRIPTION: The proposed project is a two-prong effort. Initially, the technical merits of the PMP protocol would be evaluated critically, giving consideration to all of the technical aspects associated with the correlation of solid particle number emission measurements and measurements of total particle mass under the existing certification guidelines. The ARB currently has the required instrumentation dictated in the PMP method. Thus, some of the necessary assessment work may be carried out in house. The second phase would involve an investigation of the potential for application of the PMP method for in-use compliance testing. This task is not trivial and would entail establishing a universal and statistically significant correlation between the established measurement of total particle mass and the new proposed metric of solid particle number.

BENEFITS: The U.S. was absent from the PMP initiative as the U.S. EPA declined to actively participate. The PMP has generated leading and state-of-the-science advances in metrology for engine emissions. This project would leverage all the PMP lessons in an integrated effort with clear California benefit.

COST: $250,000

TITLE: **Light-duty Gasoline Particulate Matter: Characterization of High Emitters and Valuation of Repairs for Emission Reductions**

PROBLEM: In 2005, the statewide on-road motor vehicle inventory estimates that light-duty gasoline vehicles (LDGVs) account for as large a PM10 contribution (~40 percent) as heavy-duty trucks (~45 percent). However, the LDGV PM emissions inventory has been characterized using a much smaller database than LDGV gaseous emissions. Little emissions data exists for late model gasoline vehicles (ultra low emission vehicles and later). However, there is reason to suspect that the implementation of the low emission vehicle (LEV) programs has yielded improvements in vehicle durability and, hence, a corresponding reduction in high PM emitters.

PREVIOUS WORK: To develop the existing LDGV PM emission inventory, the ARB has funded previous research. In addition, studies by Southwest Research Institute and the National Cooperative Highway Research Program were used as data sources for determining emission factors for the inventory. From these sources, a cutpoint between normal and high PM emitters was determined for use in the inventory.

In addition, LDGV PM emissions have been investigated for toxicity. It is the case that research evidence suggests that gasoline PM may be implicated in some adverse health end-point responses. A fundamental issue is that PM emission factors that have been obtained under these toxicity studies have not been considered in the context of the inventory. In addition, the reasons for the high PM emissions have not been evaluated systematically.

OBJECTIVE: The objective of this project is two-fold. First, it includes the determination of the characteristics of the high PM emitter. Then, for the nominal high emitters, the viability, cost-effectiveness, and potential benefits of professional repairs for emission reductions will be investigated.

DESCRIPTION: The proposed project is intended to generate additional LDGV PM emission factors that may complement the inventory. The project includes the determination of the characteristics (e.g., population, vehicle miles traveled, emission factors) of the high PM emitter in relation to the California LDGV in-use fleet. The project would conduct emissions tests on a representative set of vehicles to compare PM and volatile organic compound emissions from both black smokers (e.g., vehicles out of tune or with broken components) and blue smokers (e.g., oil burners with worn out components). The project will define criteria for identification of high PM emitters and will determine a nominal profile(s) for the high PM emitting vehicle(s). Finally, the project will investigate the potential for professional repairs to yield reductions in PM emissions from the high emitter.

BENEFITS: A key issue facing ARB is a better understanding of the role that motor vehicles play in the total burden of ambient PM. LDGVs represent the most ubiquitous combustion source in California and their PM emissions have changed significantly over the past 25 years. Because of evolving tailpipe emission profiles, along with the wide variability of emissions between vehicles of the same class, additional information on emission-source profiles for the major contributors of motor vehicle PM emissions are needed.

COST: $250,000

TITLE: **Carbon Dioxide Emission Quantification from Vehicle Air Conditioning Operation**

PROBLEM: Vehicle air conditioning (A/C) systems contribute significantly to exhaust carbon dioxide (CO_2) emissions. This is largely due to the added load on the engine from A/C system operation. The resulting CO_2 emissions depend on the A/C system design and control as well as parameters that impact the vehicle solar load, such as glass angles, window glazing, interior and exterior colors, and cabin insulation.

In ARB's recently adopted greenhouse gas regulation, credits are awarded for a limited group of A/C system modifications that reduce CO_2 emissions. The value of the credits is based on estimates from vehicle simulation modeling because a reliable and comprehensive test method has not been developed for measuring the impact that vehicle A/C system operation has on CO_2 emissions under "real-world" conditions.

PREVIOUS WORK: The Supplemental Federal Test Procedure (SFTP) prescribes a test method for quantifying emission impacts from A/C system operation. Vehicle testing is performed with the A/C system operating at maximum capacity within an environmental test chamber maintained at 95°F and equipped with high intensity solar lamps. The test procedure is beneficial for limiting vehicle emissions under conditions of heavy A/C usage.

OBJECTIVE: The objective is to develop a whole vehicle test procedure for measuring the impact that vehicle A/C system operation has on CO_2 emissions in "real-world" conditions. The procedure will then be incorporated into ARB's greenhouse gas regulation and will be used to quantify CO_2 emission reductions from technological advances in A/C system design and from features that reduce vehicle solar load.

DESCRIPTION: To properly quantify CO_2 emissions, the test procedure should be geared, where possible, to simulate typical environmental and driving conditions in California. It appears that two of the more challenging issues in developing a test procedure will be solar load simulation and the identification of representative A/C operation and controls. This second item is important in order to make a fair comparison between A/C system modifications, but requires an integration of expected operator behavior with A/C system controls.

With respect to solar load simulation, some measures within the SFTP may be transferable to the proposed test procedure, such as the use of metal halide lamps to simulate solar load. However, the lamp intensity may need to be moderated, and there may be opportunity to mitigate some deficiencies in solar load replication that occur within the SFTP (e.g. vehicle skin temperatures and heat radiation effects).

BENEFITS: A comprehensive test procedure would make it feasible for ARB to award performance-based credits for a broad spectrum of technological advancements that reduce CO_2 emissions from A/C system operation. Performance-based credits would promote further innovations that obtain real-world reductions in CO_2 emissions.

COST: $400,000

TTILE: Evaluate Greenhouse Gas Emissions from the Petroleum Sector and Determine Mitigation Strategies

PROBLEM: The petroleum sector is one of the largest contributors of greenhouse gas (GHG) emissions in the state. Although some studies have been conducted, further analysis is needed to accurately quantify the emissions and the source of the emissions as well as potential mitigation strategies.

PREVIOUS WORK: Both the California Energy Commission (CEC) and the Air Resources Board (ARB) have evaluated GHG emissions from the petroleum sector. Examples of work already completed include the well-to-wheels studies done for the ARB and refining industry modeling done for the CEC.

OBJECTIVE: The objective is to improve the understanding of greenhouse gas emissions and potential mitigation strategies associated with the petroleum industry.

DESCRIPTION: Better define GHG emissions from the petroleum industry and potential mitigation strategies.

BENEFITS: Governor Schwarzenegger's Environmental Action Plan commits to establishing greenhouse gas reduction targets for the state. Attainment of those targets will require accurate information on greenhouse gas emissions and possible mitigation measures from a variety of sectors. One of the largest contributors to GHG emissions in the state, and one of the least understood, is the petroleum industry. Better understanding GHG emissions from the petroleum industry, the sources of those emissions, and potential mitigation strategies will assist the state in working with the petroleum industry to reduce GHG emissions.

COST: $130,000

TITLE: Improving the Carbon Dioxide Emission Estimates from the Combustion of Fossil Fuels in California

PROBLEM: Central to any study of climate change is the development of an emission inventory that identifies and quantifies the state's primary anthropogenic sources and sinks of greenhouse gas (GHG) emissions. Fossil fuel combustion accounts for 98 percent of gross California carbon dioxide (CO_2) emissions. Carbon dioxide emissions are one of the best-characterized emissions in the existing state inventory, but there still exist significant sources of uncertainties. The existing inventory relies on fuel consumption reported in the State Energy Data Report (SEDR), published by the U.S. Department of Energy's Energy Information Administration (EIA). For some fuels EIA estimates consumption based on reported sales of fuels and overall energy consumption at the Petroleum Administration for Defense (PAD) Districts. Estimates of fuel consumption at the state level using a different methodology can produce significantly different results.

PREVIOUS WORK: In September 2000, the California Legislature passed Senate Bill 1771, requiring the California Energy Commission (CEC), in consultation with other state agencies, to update California's inventory of GHG emissions by January 2002 and every five years thereafter. The report concluded that there were major uncertainties associated with the inventory of GHG emissions, and recommended that future GHG inventories could be improved by: (1) incorporating improved data; (2) updating emissions estimates; and, (3) presenting a discussion of the uncertainty in emissions estimates from key sources. The CEC through the Public Interest Energy Research Program (PIER) has developed a roadmap of research on GHG inventory methods. PIER has already selected research initiatives designed to improve GHG inventory methods.

OBJECTIVE: The objective is to improve CO_2 emission inventory by estimating the level of uncertainty in the existing inventory and by determining what fuel data collection activities should be initiated in order to substantially improve the estimation of carbon dioxide emissions from the combustion of fossil fuels in the state. The work under this project should be coordinated with related PIER activities.

DESCRIPTION: Using PIER sponsored research as a starting point, two PIER reports are of particular importance: 1) the Energy Balances Report and 2) the Roadmap of Research on GHG Inventory Methods. The differences in fuel consumption data reported in different reports and data sets should be used as a starting point to estimate the level of uncertainty in the existing CO_2 emission estimates. The carbon content of the different fuels is not measured but inferred from the technical literature. The analysis should include an analysis of this source of uncertainty. Finally, the study should recommend data collection activities that the state should implement to improve its CO_2 emission estimates.

BENEFITS: Improved emission estimates for greenhouse gases are needed for evaluating the effects of existing and planned air quality programs on carbon dioxide emissions in the state. More accurate fuel consumption data may also allow improving the estimation of criteria pollutant emissions.

COST: $75,000

TITLE: **Clearinghouse of Technological Options for Reducing Anthropogenic, Non-Carbon Dioxide Greenhouse Gas Emissions from All Sectors**

PROBLEM: Emissions from a broad spectrum of sources including residential, industrial, commercial, electricity generation, and transportation are contributing to climate change. To date, much of the effort to characterize emissions as well as identify opportunities for emission reductions have focused on carbon dioxide (CO_2). However, while CO_2 (natural and anthropogenic) has been recognized as a dominant greenhouse gas (GHG), an integrated effort for global climate protection is underway that considers anthropogenic, non-CO_2 GHG emissions, nitrous oxide (N_2O), hydrofluorocarbons (HFCs) perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6) from important sectors when considering the global warming potential (GWP) of the GHGs. Specifically, when considering the GWP of the pollutants emitted as well as the options available for reducing emissions, there may be cost-effective, readily available options for realizing significant emissions reductions from several sectors. Estimates of non-CO_2 GHG emission reductions by sector and the identification of the enabling technology for such reductions are desirable, but presently not readily available.

PREVIOUS WORK: In California, the California Energy Commission (CEC) has led early climate change analyses, starting with its 1988 legislative mandate to study global warming trends. The CEC's efforts have included the development and update of GHG emission inventories. The CEC is presently sponsoring an effort to develop non-CO_2 GHG supply curves for California where they are highly focused on the identifying the potential to reduce CH_4, N_2O, and other high global warming potential compounds (e.g., refrigerants). In addition, the existing research literature contains excellent general discussions on technology developments and innovations that can be used for GHG emission reductions from various sectors of interest. However, most of these discussions do not focus on non-CO_2 GHGs. Therefore, the resulting suggestions for improvement have emphasized cleaner fossil fuels, the hydrogen economy, and advanced end-use technology (e.g., intelligent buildings).

OBJECTIVE: The objective is to develop an international clearinghouse of technological options that have been employed for reducing anthropogenic, non-CO_2 GHG emissions from sectors which are relevant to California.

DESCRIPTION: The project is a paper study of the existing literature to determine (1) all of the relevant sources of non-CO_2 GHG emissions in California and (2) the technology options for emission reductions. As such, there is an opportunity for leveraging this work with that of the CEC.

BENEFITS: The information is needed to advance the debate about California's efforts in global climate protection. The work would contribute towards efforts to better characterize cost-effective opportunities for reduction in non-CO_2 emissions from both motor vehicles and stationary sources.

COST: $50,000

TITLE: Impact of Climate Change Meteorological Variables and Urban Air Quality in California

PROBLEM: Weather is a key variable affecting air quality. Surface concentrations of pollutants are highly sensitive to mixing depth, boundary layer ventilation, winds, temperature, humidity, and other meteorological variables. As greenhouse gas concentrations increase and rapid climate change takes place over the next century, the consequences for air quality are likely to be significant but the magnitude is uncertain. Most climate models estimate a continuation of asymmetric changes in diurnal temperature (more nocturnal warming). A need exists to systematically identify the important linkages between air quality and climate so that the important drivers for future changes to air quality are understood.

PREVIOUS WORK: Previous investigations have determined the direct sensitivity of ozone and airborne particulate matter (PM) to temperature. For example, Kleeman et al. (2004) estimated an increased ozone level but decreased PM concentrations with higher temperatures in a region in California. However, this study assumes a uniform increase of diurnal temperatures, which is not in agreement with observed trends and the output of most climate models.

OBJECTIVE: The objectives are to: 1) assess the impacts on regional air quality from climate-induced meteorological and emission changes, 2) quantify the sensitivities and uncertainties in climate change impacts, and 3) determine if climate change forcing has potentially significant and probable impacts on the direction and magnitude of air pollution changes and on the effectiveness of control measures being considered for improving ozone and PM air quality in major urban areas in California.

DESCRIPTION: The goal of this research project is to identify important linkages between climate and air quality for major urban areas in California. The regional air quality assessment should focus on the effects of climate variability and change, especially related to meteorological variables such as variations in mixing depth, temperature, and relative humidity, on ground-level ozone and PM production. Available empirical data on meteorological and air quality relationships will be coupled with the selected climate scenarios to estimate changes in ground-levels of ozone and PM. Air quality modeling in conjunction with online sensitivity analysis techniques can be used to quantify how ozone and PM levels and duration of the high air pollution concentrations respond to changes in key meteorological factors such as mixing depths, frequency of stagnation episodes, regional ventilation, etc.

BENEFITS: The study will provide an integrated assessment of the effects of climate change on ozone and particulate matter air quality in California. Better understanding of the linkages between air pollution problems on local, regional, and global scales will help support more cost-effective allocation of federal and state environmental protection resources.

COST: $300,000