STATE OF CALIFORNIA
AIR RESOURCES BOARD

MEETING OF THE

RESEARCH SCREENING COMMITTEE

January 31, 2014
9:00 a.m.

Air Resources Board
Research Division
Cal/EPA Building
1001 I Street
Sacramento, CA 95814
(916) 445-0753

State of California
AIR RESOURCES BOARD

Research Screening Committee Meeting
Cal/EPA Headquarters Building
1001 I Street
Conference Room 510, 5th Floor
Sacramento, California 95814
(916) 445-0753

January 31, 2014

9:00 a.m.

AGENDA

State of California
AIR RESOURCES BOARD

Research Screening Committee Meeting
Cal/EPA Headquarters Building
1001 I Street
Conference Room 510
Sacramento, California 95814
(916) 445-0753

October 18, 2013
9:00 a.m.

MINUTES

RSC Members in Attendance via teleconference

Steven Japar
Irva Hertz-Picciotto
Suzanne Paulson
Rachel Morello-Frosh
Alan Vette
William Eisenstein
Philip Fine

The Research Screening Committee (RSC or Committee) convened the meeting at 9:07 a.m. The minutes of the May 17, 2013 meeting were approved.

I. Draft Final Reports

1) "Persistent Immune Effects of Wildfire Particulate Matter Exposure during Childhood Development," University of California, Davis, $268,029, Contract No. 10-303

   A Committee member inquired whether cytokines other than IL-6 and IL-8 were measured, and whether or not the Principal Investigator had studied whether there were differences in animal population density between 2008 and 2009, the years during which study animals were born. Staff responded that only IL-6 and IL-8 were measured in the study, and that the investigator could be asked to address the population question in the revised final report. The Committee member also asked that the investigator clarify that the conclusion on epigenetic changes was based on gene expression data, and not on direct measurement of DNA methylation.

   Motion: Move to accept subject to the inclusion of comments from staff and Committee.

   The Committee approved the report.

2) “In-Duct Cleaning Devices: Ozone Emissions Rates and Test Methodology,” University of Missouri Science & Technology, $325,000, Contract No. 09-342

Staff informed the Committee that Underwriter’s Laboratories advisor was out of the country and the Consumer Products Safety Commission advisor was out because of the government shutdown, so neither of them could complete their review before the RSC meeting. Both advisors indicated that they were generally pleased with the report and that they had only minor comments so far, so staff was not expecting any comments of significance. Staff expected the full set of comments from the advisors the following week.

A Committee member felt that the report provided a comprehensive test method, and also provided some model validation that would help the State to develop an actual emission standard for ozone coming from in-duct devices. The Committee member further commented that the test method, as developed, is very comprehensive but might be burdensome for some manufacturers to carry out. As ARB moves forward, they may want to consider some simplification of the method, or have some options for some type of screening test so that manufacturers are not put off by such a detailed test method.

Motion: Move to accept subject to the inclusion of comments from staff and Committee.

The Committee approved the report.

3) “Quantifying the Effect of Local Government Actions on Vehicle Miles Traveled,” University of California, Davis, $125,000, Contract No. 09-343

One Committee member stated that this was very good study and a valuable contribution to the literature. The Committee member provided an overview of recommended improvements that were described in detail as part of the written comments. There were two groups of comments: 1) recommended improvements that should be made to the report before it is finalized and 2) improvements for consideration for future efforts to build upon the report results. Verbal comments provided during the meeting focused on the first group of comments only. The Committee member suggested that the results be discussed more thoroughly in the context of AB 32 and SB 375. The Committee member also suggested providing summary tables for local planners that could serve as takeaway guidance and rank-order the list of policies according to the potential to reduce vehicle miles travelled (VMT). The member also suggested emphasizing the finding more strongly, stating that the differences in VMT reductions between neighborhood types is quite large. Another Committee member stated that the report had some interesting findings, but the style of communication for the tables and figures was frustrating and could be improved with better improved captions. Based on the response to the comments document, the Committee member acknowledged that staff would work with the Principal Investigator to make these changes.

Motion: Move to accept subject to the inclusion of comments from staff and Committee.

The Committee approved the report.

4) "Residential Energy Use and Greenhouse Gas Emissions' Impacts of Compact Land Use Types," University of California, Berkeley, $100,000, Contract No. 10-323

A Committee member asked a clarifying question about one of the written comments raised by another member. The Committee member asked how staff responded to the question, "Are the authors technological optimists who believe that energy efficiency will sharply improve so that homes built in the future will use less electricity per square foot?" Staff explained that the written response to the comment states that there are two options for estimating future energy usage. One option is based on modeled energy use in the recent past and the other is based on future updates to the Title 24, Building Energy Efficiency Standards, which does assume improved energy efficiency. The Committee member asked if the user of the tool is able to pick between those two options. Staff confirmed that yes, this is the case.

Motion: Move to accept subject to the inclusion of comments from staff and Committee. William Eisenstein recused himself from the discussion of this item.

The Committee approved the report.

5) "Inverse Modeling to Verify California's Greenhouse Gas Emission Inventory," California State University, East Bay, $150,000, Contract No. 09-348

Motion: Move to accept subject to the inclusion of comments from staff and Committee. William Eisenstein abstained from voting.

The Committee approved the report.

6) "Assessment of Nitrous Oxide Emissions in California's Dairy Systems," University of California, Davis, $82,000, Contract No. 09-325

One Committee member submitted written comments asking for clarification in a few areas, including the format of the Figure 1 legend, an explanation for a missing emission rate for one growing season of corn for one field, and the different regression outcomes obtained for two fields on Farm A. Staff responded that the Principal Investigator will fix the Figure 1 legend, and explained that the lack of emission estimate was due to data gaps in measurements for that particular field, and that the different regression results were normal for agricultural cropping systems due to the variability of the field conditions. The Committee member requested addition of the explanation in the final report.

Another Committee member requested the addition of an appendix for the inclusion of the calculations of the emission rates from the chamber

concentration measurements, and an explanation for one notation used in the report. Staff indicated that the PI will provide the requested information.

Motion: Move to accept subject to the inclusion of comments from staff and Committee.

The Committee approved the report.

7) "Assessment of Nitrogen Oxides (NO_X) Emissions from Soil in California Cropping Systems," University of California, Davis, $83,500, Contract No. 09-329

The Committee is expressed a desire to get bounds of emission estimates for NO_X from agricultural soils in California. Staff indicated that estimation of emission rates was beyond the scope of the study. Staff will work with the researchers to develop such estimates, if possible.

Motion: Move to accept subject to the inclusion of comments from staff and Committee.

The Committee approved the report.

II. Responses to a Request for Proposals

1) "Technical Analysis of Vehicle Load-Reduction Potential for Advanced Clean Cars," RFP No. 13-313

Motion: Move to accept proposal.

The Committee approved the proposal.

III. Other Business

1) Update on Annual Research Plan

Staff provided the Committee with an update on the Research Plan Process. The current status of the Plan is that staff is working on the research project descriptions. The project write-ups will be delivered to the Committee soon for review. The Solicitation will go out mid-November, with projects due in early January. The accepted proposals will be reviewed by the Committee at the May RSC meeting. A Committee member questioned whether the RSC approves or just provides input for the projects. Staff responded by explaining that the RSC provides input on the technical aspects of the projects, but the Board considers the Plan at the December Board Hearing.

The meeting adjourned at 10:15 a.m.

DISCUSSION OF A NEW RESEARCH PROJECT
ITEM NO.: II.1
DATE: January 31, 2014
PROPOSAL NO.: 2768-277

STAFF EVALUATION OF AN INTERAGENCY RESEARCH PROPOSAL

TITLE:	Characterizing the Climate Impacts of Brown Carbon
PRIME CONTRACTOR:	University of California, San Diego, $200,000
SUBCONTRACTORS:	University of California, Davis, $202,500 Stanford University, $50,000
PRINCIPAL INVESTIGATOR:	Lynn Russell, Ph.D.
TOTAL AMOUNT:	$452,500
CONTRACT TYPE:	Interagency Agreement
CONTRACT TERM:	36 months

For further information, please contact Dr. Dongmin Luo at (916) 324-8496.

I. SUMMARY

Black carbon (BC, the dark soot produced from combustion) absorbs light and gives off heat, and is now recognized as a significant contributor to global warming. Light-absorbing organic carbon (OC) that is not black, called brown carbon (BrC), was recently discovered to also be a potentially large contributor to global warming. The combustion sources that contribute to BrC in the atmosphere are not well characterized, and recent studies suggest that there may be multiple pathways for its formation. To help characterize and differentiate sources of BrC from BC, the proposed research will apply advanced instrumentation that will provide unprecedented chemical and optical characterization of BrC sources and investigate its formation pathways. These measurements will be used to separate and characterize BrC, and quantify its importance in regional and global modeling climate forcing. This project will improve our understanding of the fundamental processes that govern BrC formation and its evolution

in the atmosphere, and help us determine the potential climate benefits of mitigating emission sources of BrC in California.

II. TECHNICAL SUMMARY

Objective

This research project will identify and characterize the contribution of BrC to climate forcing in California by 1) providing state-of-the-art real-time measurements at two California locations for determining the chemical concentrations and optical properties of burning activities; 2) quantifying the BrC organic components and the multi-wavelength absorption from burning emissions and from atmospheric formation of secondary components; and 3) examining the globally and regionally-averaged climate response of BrC.

Background

Airborne particulate matter (PM) varies in its composition and plays a significant role in human health and the climate system. Among different types of PM, carbonaceous PM, containing OC and BC, is especially important because of its abundance in the atmosphere, and its health effects, which are the focus of increasing interest. With respect to climate impact, BC is the principal absorber of visible solar radiation in the atmosphere, whereas OC is often described as light-reflecting. Recent studies show that certain OC fractions can also absorb solar radiation efficiently, although they differ from typical BC; these fractions are referred to as “brown carbon.”

Although BrC is pervasive in the atmosphere, neither its sources nor the extent to which BrC contributes to direct aerosol climate forcing are well understood. BrC emissions released from residential, agricultural, and wildfire burning activities are highly seasonal or episodic, and thus are a poorly characterized fraction of PM2.5 in California. Because their emissions are highest in the winter months when air quality is worst in the San Joaquin Valley (SJV) and Sierra foothill communities, quantifying their role in the atmosphere is essential both to improving local air quality and to understanding climate impacts. In addition, secondary organic aerosols formed from urban emissions provide another source of BrC. For example, aqueous oxidation during fog episodes in the South Coast Air Basin (SoCAB) produces light-absorbing organic compounds.

Climate modeling and monitoring research has mainly focused on the atmospheric concentrations of BC and OC and their estimated effects on global warming. Since BrC is potentially an important contributor to atmospheric warming, estimates of the warming effect purely based upon BC and OC alone are insufficient. BrC should be incorporated into climate models, and its impact on net forcing needs to be estimated. This research study will help to identify sources of BrC and quantify its relative contribution to the absorption of solar radiation by PM. This will allow for improved assessment of the potential climate benefit of reducing specific PM sources with high OC emissions that are determined to be large contributors to BrC.

Proposal Summary

The goal of this project will be accomplished through the completion of the following three tasks, which cover observational data and observationally-constrained climate model assessment.

Task 1: Characterize and differentiate sources of BrC from BC

The proposed research will include measurements for about two weeks during the summer of 2014 and two weeks during the winter at two California sites (to be selected in consultation with ARB staff to leverage other studies and facilities) that investigate at least two types of BrC (e.g., residential burning and urban secondary organic aerosols). Ambient organic aerosol will be chemically characterized and source-associated using complementary techniques: mass fragments by real time Aerosol Mass Spectrometry (AMS) and functional groups by Fourier Transform Infrared (FTIR) spectroscopy. Similarly, complementary multi-wavelength optical measurements will be made in real time using Cavity Ring-Down (aerosol extinction spectrometer) and Photo-Acoustic Spectroscopy (CRDPAS), and on collected samples using Ultraviolet-Visible Absorption of the Water-Soluble (extractable) Organic Carbon (WSOC/UV-VIS) and the IMPROVE Hybrid Integrating Plate/Sphere (HIPS) system. Through measurement of the wavelength dependence of the aerosol optical properties it is possible to discriminate the contributions of BC from other absorbing materials. Furthermore, the combination of the AMS and FTIR approaches allows for more accurate identification of different

organic particle types. The high time resolution (5 min) of the AMS produces detailed time series of organic molecular fragments, which can be associated with source plumes. FTIR measurements will be made for ambient particles, typically for sampling times of 4 to 12 hours. Black carbon number and mass concentrations will be made using a single particle soot photometer (SP2), and particle size distributions will also be measured.

Task 2: Quantify chemical and optical characteristics of BrC sources and examine the formation of secondary BrC

The goal of Task 2 is to use statistical analysis methods to separate and characterize the BrC component of organic aerosol. A major analysis tool to be used to characterize and quantify BrC separate from other organic components will be Positive Matrix Factorization (PMF). Specifically, PMF will be used to attribute the measured mass of OC functional groups to sources based on FTIR and AMS organic signatures and XRF metal tracers, compare these chemical signatures for burning and urban smog with the multi-wavelength optical measurements, and evaluate the characteristic spectral absorption of both urban fog-smog and wintertime burning activities. Overall, the goal of this work is to effectively separate BrC sources and obtain differential absorption for some of the sources. It requires a combination of AMS, FTIR, CRDPAS, and SP2 to successfully isolate and separate: 1) different sources of BrC; 2) different chemical compositions of BrC; and 3) BrC from BC.

Task 3: Assess net contribution of BrC to California climate

The investigators will compare the BrC concentrations and properties evaluated in Tasks 1 and 2 to the concentrations and properties of biomass burning and other BrC sources included in regional and global climate models. This task consists of three parts, namely two types of model simulations and a column-observation-based calculation: source-oriented WRF-Chem (Weather Research and Forecasting (WRF) model coupled with Chemistry) regional simulations, Gas, Aerosol, Transport, Radiation, General Circulation, Mesoscale, and Ocean Model (GATOR-GCMOM) global and nested regional simulations, and chemically and optically constrained climate

forcing estimates. These multiple methods for assessing the BrC climate forcing are essential to constrain both the regional and global BrC impacts (with WRF-Chem and GATOR-GCMOM), the specific indirect effects that contribute to them (with WRF-Chem), and the uncertainty compared to observational constraints with AErosol RObotic NETwork (AERONET) data.

Projected twenty-year global simulations (2010-2030) with and without BrC will be run to examine the globally and regionally-averaged climate response of BrC. Two one-year simulations nested from the globe to California will be run, one with and one without all BrC. Results from the baseline simulation will be compared with BrC measurements gathered as part of the project. Based on the initial comparison with data, a sensitivity pair of simulations will be run to test whether modifying the emission rate of BrC improves the comparison with data or affects the climate response estimate. The Source-Oriented WRF-Chem (SOWC) model will be used to simulate air quality in California over the same two 1-year periods as well. The SOWC model predictions for BrC absorption and total absorption will be compared to the GATOR-GCMOM model predictions for the same variables. The degree of mixing for light absorbing components with other aerosol components will be compared between the two models to better understand differences in optical signatures. SOWC model predictions for total absorption and BrC absorption will also be compared to measurements as an absolute test of model performance.

Part of the Task 3 assessment of net contribution of BrC to climate uses *in situ* measurements. This work provides an additional set of column observations above the ground surface measurements that will be used to constrain climate forcing and to provide a direct comparison to modeled column properties. This task will use the *in situ* chemical and physical data collected by tasks 1 and 2 to calculate the BrC optical depths and climate forcing over the two California sites selected for sampling, and compare results with the optical depths and climate forcing estimated independently with the nearest available AERONET data.

III. STAFF COMMENTS

An earlier version of the proposal was reviewed by staff and the current version has incorporated staff comments to improve its clarity. The reviewers generally recognized the quality of the proposed research effort and the practical importance of the results. Overall, the level and quality of effort is adequate; the investigators have proposed enough labor to ensure successful completion of this study.

Dr. Russell (UCSD) will serve as the Principal Investigator coordinating and synthesizing the effort of other task leaders, in collaboration with Dr. Cappa and Dr. Kleeman (University of California, Davis), and Dr. Jacobson (Stanford). Dr. Russell has unique expertise in the measurement and source apportionment of organic aerosols. Dr. Cappa has designed and developed the highest resolution online measurement of aerosol 2-wavelength absorption and extinction by submicron particles to distinguish absorbing and non-absorbing organic mass. Dr. Jacobson has designed GATOR-GCMOM, the most comprehensive global climate model with the ability to carry out nested regional simulations. Dr. Kleeman is the inventor of the first source-oriented WRF-CHEM model version, which provides unique capabilities in linking climate impacts with specific aerosol sources.

IV. STAFF RECOMMENDATION

Staff recommend the Research Screening Committee approve this proposal for a total amount not to exceed $452,500, subject to any changes and additions specified by the Committee.

DISCUSSION OF A DRAFT FINAL REPORT
ITEM NO.: IV.1
DATE: January 31, 2014
CONTRACT NO.: 10-332
Link to Report

STAFF EVALUATION OF A DRAFT FINAL REPORT

TITLE:	Behavioral Responses to Real-Time Individual Energy Usage Information: A Large Scale Experiment
CONTRACTOR:	University of California, Los Angeles
PRINCIPAL INVESTIGATOR:	Magali Delmas, Ph.D.
CONTRACT TYPE:	Interagency Agreement
BUDGET:	$322,003
CONTRACT TERM:	45 months

For further information, please contact Annmarie Rodgers at (916) 323-1517.

I. SUMMARY

Reductions in energy usage in the residential sector are needed in order for California to meet its greenhouse gas (GHG) reduction goal. This project investigated how real time appliance level energy usage information provided through advanced metering technology can induce conservation behavior. This research leveraged a large asset of advanced residential energy monitoring technology deployed in 120 apartments in Los Angeles. The residents were given feedback to optimize motivations to reduce energy use. The message formats varied to identify best practices and optimal messaging. The researchers compared the effectiveness of messages based on the environmental or health benefits associated with conservation to more conventional messages focused on the pecuniary savings associated with conservation. The results show that health based messages, which communicate the public health externalities of electricity production, outperform monetary savings information as a driver of behavioral change in the home. Participants who received messages emphasizing air pollution and health impacts associated with energy use reduced their consumption by 6 percent over the experimental period as compared to the control group. Health messaging was

particularly effective on families with children, who achieved up to 19.8 percent savings. No significant conservation was found for participants who received messages informing them about monetary savings. These results advance our knowledge of effective non price incentives for energy conservation and provide tools for California to meet its climate goals.

II. TECHNICAL SUMMARY

Objective

This project was designed to test the long-term effectiveness of real-time energy consumption feedback coupled with various forms of positive encouragement and social recognition aimed at reducing electricity consumption in the residential sector.

Background

Residential and commercial buildings collectively account for over two-thirds of electricity usage and about a quarter of carbon emissions in the U.S. The large impact of building energy usage is not surprising considering that residents of the U.S. spend more than 90 percent of their lives indoors. Recent studies estimate that behavioral changes can reduce residential energy consumption between 22 and 30 percent over the next 5 to 8 years. One potentially major behavioral innovation aims to provide more detailed feedback to consumers about their energy usage, both in the private and public spheres. While currently most U.S. residential electricity consumers receive low resolution feedback through a monthly bill, the massive deployment of more than 65 million digital electricity meters by 2015, will allow utilities to provide a wealth of new information to more than half of the nation’s electricity accounts, unlocking new conservation potential. However, this substantial upgrade to smart meter technology (representing $16 to $32 billion in investment) is not countered by an equally sound understanding of the conservation behavior opportunities associated with these new technologies.

Project Summary

This study investigated how real time appliance level energy usage information provided through advanced metering technology can induce conservation behavior. The researchers outfitted 120 family apartments at a graduate housing community in

Los Angeles with wireless energy metering technology. They measured electricity use data in real-time, 24 hours a day at the appliance level. The apartments are standardized in size and have the same appliances, so that there are no differences in energy efficiency or size in the housing stock. This consistency promotes the validity of experimental effects of energy use as resulting from individual behaviors and lifestyles, not differences in apartment features. The residents had adequate control of their environment (lights, thermostats, plug load, fridge, dishwasher and other appliances) to meaningfully engage in conservation. On a per capita electricity basis, University Village residents are representative of the State of California multi-family renter populations. While the residents consist of single and married graduate college students, who are younger and more educated than the U.S. population, they represent the next generation of homeowners who are used to working with mobile electronic devices and increasingly rely on electronic communications in their daily lives.

One group of apartments was given detailed energy use feedback along with information about monetary savings. Another group was given feedback with an environment and health message about emissions and air quality impacts such as childhood asthma and cancer. A third group served as a statistical control following a six-month baseline period and random assignment. Statistical methods were used that compared the effectiveness of the detailed energy feedback on energy consumption for the treatment groups compared to the control group. The specifications consider treatment status along with other factors that may influence energy consumption such as household characteristics, apartment characteristics, environmental ideology, and weather.

There was an overall treatment effect of a 6 percent reduction in energy usage with environment and health messaging over the entire experimental period—after controlling for observed household characteristics, occupancy, weather, time trends, and environmentalist ideology. Using published price elasticities for California, this conservation effect is equivalent to a long-run electricity price increase of 15.4 percent or a 60-day short-run price increase between 23 and 45 percent. This was particularly effective on families with children, achieving up to 19.8 percent savings relative to the

control group. On average, participants who only received information about potential monetary savings did not significantly alter their energy consumption.

These results advance our knowledge of effective non-price incentives for energy conservation. While non-price behavioral strategies can be viable alternatives to new capital projects by promoting peak load shifting and conservation, they can also be implemented immediately, at scale and at relatively low cost. Behavioral strategies enabled through information technologies can be an effective component of sustainable development pathways and do not require long lead times typical of new capital investments in energy generation, distribution and storage.

III. STAFF COMMENTS

Staff at ARB (Research and Stationary Source Divisions), the California Energy Commission and Lawrence Berkeley National Lab reviewed and provided comments on this report. Reviewers found the report to be clear, well-written, and easy-to-read. All of the reviewers were impressed with the 6 percent reduction in energy use and suggested that it would be interesting to see how long the observed 6 percent average savings persists after the study intervention is complete.

Dr. Delmas has presented an important observational study regarding the short-comings of approaches to energy conservation that focus purely on appeals to consumers' financial self-interest, rather than leveraging other motivations (e.g., concerns about environment, health, and/or status). This report provides insight for future outreach campaigns from investor owned utilities and other organizations interested in reducing residential energy use. The project also highlights the importance of supporting future behavioral research projects to maximize these proven benefits in reducing residential energy use and the effectiveness of applying multiple outreach campaigns that target pricing education, peer-comparisons and incentives in combination should be explored.

Results from this project were presented at an ARB research seminar in August 2013, along with the results from two other ARB-funded projects on the behavioral aspects of energy use reduction in the residential sector

(http://www.arb.ca.gov/research/seminars/delmas/delmas.htm). The seminar was well attended by staff from state agencies and online participation from Investor-Owned Utility (IOU) representatives. Questions and comments after the presentation largely focused on the applicability of these results to the general population in California and on the potential for employing these findings in current IOU energy saving campaigns. Due to the increasing number of IOU energy conservation programs and data feedback on customer bills, these results will help refine tactics used by IOUs and hopefully improve California's ability to meet our GHG goals in the residential sector.

IV. STAFF RECOMMENDATION

Staff recommends the Research Screening Committee accept this draft final report, subject to inclusion of appropriate additions and revisions in response to the staff comments and any changes and additions specified by the Committee.

DISCUSSION OF A DRAFT FINAL REPORT
ITEM NO.: IV.2
DATE: January 31, 2014
CONTRACT NO.: 09-327
Link to Report

STAFF EVALUATION OF A DRAFT FINAL REPORT

TITLE:	Behavioral Strategies to Bridge the Gap between Potential and Actual Savings in Commercial Buildings
CONTRACTOR:	University of California, Davis
PRINCIPAL INVESTIGATOR:	Alan K. Meier, Ph.D.
CONTRACT TYPE:	Interagency Agreement
BUDGET:	$134,981
CONTRACT TERM:	45 months

For further information, please contact Annmarie Rodgers at (916) 323-1517.

I. SUMMARY

Building operations will play a major role in cost-effectively achieving energy use and emissions reductions. Improving building operations also supports state goals for maintaining healthy indoor environments, a green economy and a clean energy workforce. This project focused on how building operators approach energy use and conservation in their work, viewing the building as a social system. It drew on interviews, a workshop, surveys, and case studies, learning from operators, other facilities staff, researchers, policymakers, and occupants. The researchers found two clusters of obstacles to lowered energy use. First, while building operators have the technical means to reduce energy use, social, organizational, and technical constraints limit ability and motivation. These include low status, customer service demands, poor feedback on occupant environment, little energy data, and shortcomings of Building Management Systems. A second cluster of obstacles rests on the fact that current combinations of buildings, management, and expectations leave many occupants dissatisfied. These results suggest that targeting building operators to implement energy reduction strategies is ideal if the following issues are addressed: 1) increasing visibility

and status of building operators; 2) improving ability to see energy; and 3) better integration of the indoor environment with energy efficiency.

II. TECHNICAL SUMMARY

Objective

This project identified behavioral, social, and organizational strategies that reduce energy use and GHG emissions from California commercial buildings; and developed improved conceptual models of how energy and comfort are managed in commercial buildings.

Background

ARB seeks to identify cost-effective options for mitigating California GHG emissions, in accordance with the California Global Warming Solutions Act of 2006 (AB 32). Supporting this act, other state policies and plans target energy use and GHG emissions reductions from commercial buildings, which account for 36 percent of California electricity use and 16 percent of direct natural gas use. The State's long term Energy Efficiency Strategic Plan specifies that 50 percent of existing commercial buildings should have consumption levels equivalent to zero net energy by 2030. California Executive Order B-18-12 ordered state agencies to take action to reduce GHG emissions by at least 10 percent by 2015 and 20 percent by 2020 relative to a 2010 baseline. In short, California has set aggressive goals for reducing energy use and GHG emissions from the state’s commercial buildings.

Theory suggests that reasonable changes in operations can save 5-30 percent of building energy consumption, but in many buildings these savings are not taken. Operations are not addressed in codes. Rules and guidelines for operational efficiency exist, but are often not followed. What operators do are a major “behavior” behind energy consumption in commercial buildings, and thus GHG emissions reductions. These opportunities have low investment costs and high savings relative to many technical efficiency upgrades. Yet even organizations that are oriented to energy efficiency miss apparently simple operational savings such as weekend thermostat setbacks, despite official guidelines directing these actions. Other researchers have noted that understanding energy efficiency investments in commercial buildings

requires comprehensive attention to the organizational and social relationships in commercial buildings, rather than isolated focus on technological efficiency or on individuals' knowledge or behaviors alone. This is also true of understanding and achieving operational energy savings.

Project Summary

To address the operational savings potential in commercial buildings, this project focused on how building operators approach energy use, energy efficiency, and energy conservation in their everyday work, seeing these actions in context of the building, devices, information, and other factors with which they interact. Overall, the goal of the project was to outline the rich potential of the position of building operators as a means of reducing energy use and improving indoor environmental quality, and to better understand difficulties to doing so.

The researchers used interviews, a workshop, surveys of 101 California buildings, and four detailed building case studies. All of these methods involved conversations with and feedback from building operators, energy managers, other facilities and property staff, building energy researchers, policymakers, and occupants. The data was analyzed to identify barriers and opportunities for achieving operational energy savings from a perspective that complements work focused on specific technological or behavioral measures.

The researchers found two principle clusters of obstacles to lowered operational energy use. First, while building operators are technically in a position to reduce operational energy use and to address performance problems in buildings, social, technical, and organizational constraints limit ability and motivation to do so. These include low status, high emphasis on customer service, poor feedback on occupant environment, little energy data, low staffing levels, low salience of energy and energy costs to the organization, and shortcomings of Building Management Systems usability and training. Building operators manage energy services in their daily work, but this only rarely constitutes strategic energy management. Often several different departments may influence energy consumption, while none "owns" energy. Levels of coordination across departments are low and some steps, in particular occupant education, are largely

omitted. Most building operators said that they did not regularly see energy bills, other sort of energy data available, if any, may be virtually unused for diagnosis. In some buildings, these obstacles had been partly overcome. These examples, as well as a larger need for better sharing of trustworthy information on what works are highlighted in the report.

A second cluster of obstacles relates to occupant satisfaction with the indoor environment and the ability of buildings to meet occupant expectations. Our analysis of occupant satisfaction survey data showed surprisingly low overall levels of occupant satisfaction with temperature and air quality, both of which are directly affected by operations. Other indoor environmental factors, especially acoustics, also rated poorly. The current combination of building design, operations, facilities management, and occupant expectations leave a high proportion of occupants uncomfortable. Not only is this bad for occupants, it can also lead to higher energy use. Energy services as provided in most are not resulting in satisfactory indoor environments, whether because of design, operations, poor commissioning, poor education, or occupant expectations that are too high.

The researchers recommend shifting the focus of building energy consumption research toward experimentation in real buildings and toward much greater inclusion of building operators, who are in an ideal position to help shape and vet solutions. Recommendations include: 1) recognizing the building as a social system and use real buildings and users to experiment with solutions; 2) supporting increases in the visibility and professionalization of building operators and operations; 3) improving technical capabilities for seeing and managing energy in buildings; and 4) better integrating indoor environmental quality with energy efficiency, both to help ensure that efficiency technologies meet their promises and so that they do not leave occupants worse off.

III. STAFF COMMENTS

Staff at ARB (Research and Stationary Source Divisions), the California Energy Commission (CEC) and Lawrence Berkeley National Lab (LBNL) reviewed and provided comments on this report. ARB staff that are working on the Scoping Plan felt that the results could potentially help building operators achieve their Leadership in Energy and

Environmental Design (LEED) certification if advanced technology alone was not producing the expected energy savings. IOUs may also include this information in the educational portion of their energy efficiency programs. Staff at the CEC and LBNL felt that information from this report added to the foundational research on important aspects of behavioral energy efficiency. There is a hope that research like this will help build the argument for the inclusion of operation specifications in building codes. LBNL staff recommended that future research should quantify actual energy savings from implementing the suggested strategies.

The researchers met their goal of defining how building operators approach energy use and outlined barriers to energy efficiency in the management of commercial buildings. The researchers developed recommendations that could help to overcome these barriers. ARB Research Division staff hope to use our outreach tools, such as seminars, research notes and fact sheets to increase the awareness of these research results. A seminar is planned for May to present the research results of this and another research project on commercial building energy use behavior. By inviting staff from IOUs, federal and state agencies and the general public, we hope to disseminate the information from these projects to relevant stakeholders.

IV. STAFF RECOMMENDATION

Staff recommends the Research Screening Committee accept this draft final report, subject to inclusion of appropriate additions and revisions in response to the staff comments and any changes and additions specified by the Committee.

DISCUSSION OF A DRAFT FINAL REPORT
ITEM NO.: IV.3
DATE: January 31, 2014
CONTRACT NO.: 10-302
Link to Report

STAFF EVALUATION OF A DRAFT FINAL REPORT

TITLE:	Location Specific Systemic Health Effects of Ambient Particulate Matter
CONTRACTOR:	University of California, Davis
PRINCIPAL INVESTIGATOR:	Dennis W. Wilson, DVM, Ph.D.
CONTRACT TYPE:	Interagency Agreement
BUDGET:	$285,866
CONTRACT TERM:	36 months

For further information, please contact Dr. Alvaro Alvarado at (916) 445-4843.

I. SUMMARY

Ambient PM (particulate matter), especially that which is less than 2.5 microns in diameter (PM2.5), is a significant public health concern due to its strong correlation with adverse health impacts related to exacerbation of both pulmonary and cardiovascular disease. Although the observed association has been relatively consistent, some of the the biological mechanisms through which inhaled particulate matter could influence systemic and cardiovascular health endpoints remain unclear. While regulation of PM levels is done on the basis of mass concentration within specific size ranges, there is much interest in the relative contribution of specific PM components and sources to PM-induced health effects. Classes of PM constituents thought to contribute to PM toxicity include transition metals, polycyclic aromatic hydrocarbons (PAH), and biologic material such as endotoxin. Most studies to date have focused on PM2.5 from urban areas. The extent to which known differences in PM2.5 chemical composition influences health effects in rural as compared to urban areas is largely unknown. This study compared production of mediators of blood clotting and lung and systemic inflammation in mice exposed to PM2.5 from urban and rural sites near Sacramento. It also investigated the roles of transition metals, PAH, and endotoxin in inducing the observed

effects. Lung inflammation was assessed by histopathology and measurement of markers of inflammation in lung tissue samples. Systemic markers of platelet activation and inflammation were measured in the blood. The results suggest that urban PM2.5 has greater toxicity than rural PM2.5, possibly related to PAH content, that metals do not play a significant role in mediating inflammatory effects, and that endotoxin contributes to inflammatory effects related to exposure to both urban and rural PM2.5.

II. TECHNICAL SUMMARY

Objective

The hypothesis of the study is that regional and seasonal differences in composition of environmental particulate matter from the SJV influence the nature and extent of systemic pro-inflammatory and pro-coagulant responses. The primary objective was to compare the influence of location specific ambient particle composition on pro-inflammatory mediator release and platelet activation in mice exposed by intratracheal instillation to PM2.5 collected at an urban site in downtown Sacramento and a rural site on the campus of the University of California, Davis (UCD). The second objective was to determine the relative contributions of transition metal-related reactive oxygen species generation, PAH compounds, and endotoxin on generation of systemic pro-coagulant and inflammatory responses in mice exposed as noted above.

Background

The investigators previously demonstrated that: 1) mice exposed for two weeks to concentrated ambient particles (CAPs) have altered levels of serum inflammatory mediators, and that platelets are activated to a more pro-coagulant state; 2) there is upregulation of genes associated with PAH metabolism, inflammation, and reactive oxygen species generation in the lungs; 3) the magnitude of platelet and inflammatory mediator responses and upregulation of genes in the lung appears to be season and location specific; 4) cultured human monocytes have different responses to summer and winter PM2.5; and 5) urban and rural PM2.5 contain different amounts of PAH and endotoxin.

Project Summary

BALBc mice were intratracheally instilled with an aerosolized mist of previously characterized PM2.5. The particles were collected at a rural site on the campus of UCD, and an urban site in Sacramento. In some experiments, the particles were pre-treated to neutralize endotoxin or to chelate soluble metals to investigate the relative contributions of these PM2.5 sub-species to lung and systemic inflammatory and pro-coagulant responses in different groups of mice.

Twenty-four hours after instillation, the mice were euthanized, blood was collected for serum preparation and platelet isolation, and lung tissue was prepared for inflammatory gene expression and histopathology analyses using standard methods. Thirty-two cytokines were assayed in serum samples using a commercially available assay kit to investigate several potential pathways for systemic inflammation and oxidative stress, including pathways activated by the PAHs on the particles. Platelet and monocyte activation assays were done on whole blood or on platelets collected at euthanasia using standard platelet activation assays, in addition to evaluation of interactions between platelets and monocytes, and platelets and other leukocytes. Microdissected sections of lung were analyzed for gene expression of proteins involved in PAH metabolism, reactive oxygen species responses, production of tissue specific inflammatory cytokines, and systemic activation of platelets and monocytes.

The results support the following conclusions: 1) urban source PM2.5 was significantly more pro-inflammatory than equivalent doses of rural source PM2.5; 2) metal chelation was without effect on pulmonary inflammation; 3) neutralization of endotoxin in both urban and rural PM2.5 significantly reduced pulmonary inflammatory responses; 4) urban source PM2.5 upregulated genes associated with PAH metabolism, ROS response elements, and inflammation in small airways, pulmonary arterioles, and alveolar parenchyma, pointing to the involvement of each pathway in mediating lung and systemic responses to PM2.5 exposure.

III. STAFF COMMENTS

The investigator submitted two previous drafts of the report that were reviewed by two Research Division staff. The present version incorporates the comments from the previous reviews, and was reviewed by four Research Division ARB staff and a scientist from the U.S. EPA.

Overall, the reviewers found the report to be technically sound and well written. There are several typos and minor editorial issues that should be corrected in the final version of the report. The essential information is in the report, although several points were noted where provision of more detail would aid clarity.

IV. STAFF RECOMMENDATIONS

Staff recommends the Research Screening Committee accept this draft final report, subject to inclusion of appropriate additions and revisions in response to the staff comments and any changes and additions specified by the Committee.

DISCUSSION OF A DRAFT FINAL REPORT
ITEM NO.: IV.4
DATE: January 31, 2014
CONTRACT NO.: 09-341
Link to Report

STAFF EVALUATION OF A DRAFT FINAL REPORT

TITLE:	Peripheral Blood Gene Expression in Subjects with Coronary Artery Disease and Exposure to Particulate Air Pollutant Components and Size Fractions
CONTRACTOR:	University of California, Irvine
PRINCIPAL INVESTIGATOR:	Ralph J. Delfino, M.D., Ph.D.
CONTRACT TYPE:	Interagency Agreement
BUDGET:	$274,931
CONTRACT TERM:	24 months

For further information, please contact Dr. Barbara Weller at (916) 324-4816.

I. SUMMARY

Cardiovascular disease outcomes have been associated with exposure to particulate matter (PM) air pollution in many epidemiological studies. Experimental studies have revealed potential mechanisms for these effects, which involve increases in oxidative stress and inflammation, coagulation, and changes in vascular function. Exposure studies have also examined changes in the expression of genes in key biological pathways linked to these potential mechanisms. The current study evaluated gene expression with air pollution exposure in an elderly cohort consisting of 43 subjects with coronary artery disease living in retirement communities in the South Coast Air Basin. The subjects were part of the Cardiovascular Health and Air Pollution Study (CHAPS). The exposure assessment of this study included hourly measurements of indoor and outdoor pollutant gases and daily size-specific particle mass and chemical composition. Source apportionment results in the retirement communities showed that mobile sources were the major contributors to indoor as well as outdoor particulate matter at all sites. This is important because the elderly subjects in this study spent most of their time indoors. For the analysis of gene expression, 35 genes were selected based on

biological function and also on relevance to pathways involved in air pollution effects. Results of the analysis showed an association between the exposure to traffic-related air pollutants and the expression of seven genes linked to pathways that are involved in oxidative stress response, detoxification, inflammation, and platelet activation (coagulation). This study provides additional information on the impacts of traffic pollution in the elderly with cardiovascular disease.

II. TECHNICAL SUMMARY

Objective

The objective of the study was to determine the relationship between gene expression in 43 subjects with coronary artery disease and exposure to particle mass, particle components, source tracers, and metal content.

Background

Cardiovascular disease outcomes have been associated with exposure to ambient PM air pollution in many studies. Experimental studies have found a number of mechanisms (e.g., oxidative stress and inflammation, coagulation and changes in vascular function) related to these cardiovascular disease impacts. In vitro experiments using cell cultures have shown an association between PM exposure and changes in the expression of genes involved in pathways linked to mechanisms responsible for the development and progression of cardiovascular disease. However, similar experiments need to be conducted with human populations at risk. In this study the investigators evaluated the relationship between PM exposure and gene expression changes in a well-characterized elderly cohort panel.

Project Summary

43 elderly subjects with coronary artery disease living in retirement communities in the South Coast Air Basin were evaluated for gene expression changes with changes in PM (sources, size fractions, and components) as well as pollutant gases. Whole blood samples were collected weekly using standardized methods for gene expression analysis. Gene expression data which included 35 genes involved in oxidative stress, antioxidant defense, detoxification, inflammation, coagulation, and cellular stress were available from previously funded work.

The exposure assessment was conducted previously in the indoor and outdoor environment of each retirement community and included daily size-fractionated PM mass for quasi-ultrafine particles (PM0.25), accumulation mode particles (PM0.25-2.5), and coarse particles (PM2.5-10). Primary and secondary organic aerosols (POA and SOA) were determined using the organic chemical composition from PM filters, including PAH. Hourly criteria pollutant gases, total particle number concentration, elemental carbon (EC), OC and BC were also measured.

Source apportionment funded by ARB in the retirement communities found that mobile sources were the dominant contributor to both indoor and outdoor PM2.5 at all sites. Indoor SOA formation, possibly resulting from the reaction of household products' emissions with ozone, was evident at some of the sites.

Of the 35 genes tested, positive associations were found for primary pollutants (PAH, EC, BC, primary OC, and oxides of nitrogen) with the genes involved in oxidative stress including Nrf2 gene (NFE2L2), as well as the Nrf2-mediated genes (HMOX1, NQO1, and SOD2). Traffic-related air pollutants (PAH, EC, BC, primary OC and oxides of nitrogen) were also positively associated with increased expression of IL1B (linked to an inflammation pathway), SELP (involved in platelet activation), and CYP1B1 (linked to detoxification) whose transcription is not directly Nrf2-mediated as part of an oxidative stress pathway. PM from biomass burning was significantly associated with HMOX1 (linked to an antioxidant pathway), and was positively, but not significantly, associated with the expression of seven other genes involved in oxidative stress and inflammation. Secondary air pollutants (SOA, organic acids, PM2.5 secondary organic carbon, and O_3), metals, total OC and CO were not associated with gene expression. Although many of the relationships were not statistically significant, associations were consistent with respect to their magnitude and direction across each of the genes within the pathways. No association of down regulation (decreased expression) of genes with air pollutants was found. None of the air pollutant exposures were associated with the expression of the 15 other genes associated with inflammation and oxidative stress pathway.

The effect of the response to air pollution exposure with genetic variations in three different genes (NFE2L2, SELP, and SOD2) were complex and suggest that multiple gene-gene interactions may be involved, including many genes which were not assessed.

The increased expression of genes, particularly in oxidative stress response and coagulation pathways, is consistent with the scientific literature. This study provides additional evidence on the mechanisms of cardiovascular disease progression from traffic related PM exposures in the elderly.

III. STAFF COMMENTS

Several Research Division staff reviewed the first draft of the final report. Staff with differing areas of expertise reviewed both the health and exposure analyses in the report and provided comments for additions and clarifications. Comments included requests for additional information on the original cardiovascular study and additional information on limitations and exposure methods. The second version of the draft report was extensively modified based on staff comments. The draft report is formatted so that each chapter relates to a specific task of the study. The chemical analysis and source apportionment methods and results in the draft final report are being reviewed by Research Division staff with expertise in this area.

IV. STAFF RECOMMENDATIONS

Staff recommends the Research Screening Committee accept this draft final report, subject to inclusion of appropriate additions and revisions in response to the staff comments and any changes and additions specified by the Committee.

DISCUSSION OF A DRAFT FINAL REPORT
ITEM NO.: IV.5
DATE: January 31, 2014
CONTRACT NO.: 10-321
Link to Report

STAFF EVALUATION OF A DRAFT FINAL REPORT

TITLE:	Using Remote Sensing to Quantify Albedo of Roofs in California's Seven Largest Cities
CONTRACTOR:	Lawrence Berkeley National Laboratory
PRINCIPAL INVESTIGATORS:	George Ban-Weiss, Ph.D. Jordan Woods Ronnen Levinson, Ph.D.
CONTRACT TYPE:	Standard Agreement
BUDGET:	$250,000
CONTRACT TERM:	36 months

For further information, please contact Dr. Eileen McCauley at (916) 323-1534.

I. SUMMARY

Cool roofs reflect a fraction of incident sunlight that would otherwise be absorbed and heat commercial buildings and residences. The reflection of incident light also counteracts some of the greenhouse effects from absorbed radiation. Of critical importance for the prediction of benefits from a large scale cool roof (and cool pavement) climate change mitigation policy is the understanding of current reflectances (albedos) of major urban centers in California, such as Los Angeles, Long Beach, San Diego, Bakersfield, Sacramento, San Francisco, and San Jose. In this project, the investigators used multi-band aerial imagery, ground-truth field work, and statistical/spatial simulations to determine reflectances for these major urban centers. They also found, by using a limited simulation, some potential in using cool roofs for climate change mitigation, as well as for avoiding heat island effects in Bakersfield. Results from this work include both a database of roof reflectances for major urban centers and a method to generate reflectance data from aerial imaging, which is useful for creating similar albedo databases for other urban centers.

I. TECHNICAL SUMMARY

Objective

Widespread implementation of cool roofs (and cool pavements) has been considered as an important element in climate change policy for several reasons: replacing a dark roof with a white roof can decrease heat flows into the conditioned space and lower cooling energy use; solar reflective roofs transfer less heat to the atmosphere than dark roofs, lowering surrounding air temperatures; and wide use of reflective roofs mitigates some greenhouse effects. The primary objective of this work was to characterize existing roof reflectances for major urban centers of California; this baseline can then be used to gauge overall benefits possible from wide-scale adoption of a cool roof policy.

Background

The CEC has long promoted the energy saving benefits of cool roofs and pavements by advancing policies to help cool roof products come into the market, finding ways for cool roofs to count towards energy efficiency compliance, and requiring cool roofs to be included in commercial built environments. In these steps, the Cool Roof Rating Council has been a key vehicle for the LBNL and the CEC to standardize and certify cool roof products.

In the last five years, as studies have demonstrated that wide-scale use of white and cool roofs can reduce temperature in the regional environment by up to 0.3°C and simulations have shown the potential for negating some fraction of absorbed radiation, cool roofs and pavements have received attention as an important element of climate change mitigation policy. Recommendation of this policy to decision-makers, however, requires large-scale bottom-up simulations that utilize accurate parameterizations of existing roof stocks and their albedo. This project helped fill these data gaps by providing measurements and analyses of reflectances for existing roofs in California.

Project Summary

The researchers for this project characterized reflectances of roofs in major urban areas of California by using a combination of methods: existing aerial multi-band radiation data collected over California; statistical/spatial methodologies, such as Geographic Information Systems, statistical pixel assignments, Monte Carlo simulation; and field

campaigns for ground-truthing. Results from this work include roof reflectances for Los Angeles, Long Beach, San Diego, Bakersfield, Sacramento, San Francisco, and San Jose. Five of these major urban centers have average reflectance of 0.17, and the other two have values that range from 0.2 to 0.29. A significant fraction of existing roofs have small surface areas (<400 m^2) and have low reflectances (0.14 to 0.17); these offer a specific target for policy action. A roof with minimal aged reflectance of 0.35 is considered cool, which leaves significant room for improvement. Simulations for Bakersfield, though very limited, suggest that a modest cool roof implementation scenario may reduce peak temperatures in Bakersfield by 0.2°C (separate from an urban forestry and cool pavement programs which would likely be part of such mitigation efforts).

III. STAFF COMMENTS

Staff from ARB's Research Division and the California Energy Commission reviewed and provided comments; the principal investigators agreed to address all requests in a revised report.

To understand the content of this report, a recollection of the regulatory development in this area is needed. White roof adoption in the Title 24 Building Energy Efficiency Standards, though proposed earlier, came into effect in 2008. The downturn in new housing construction began in late 2007. Data collection of multi-band radiation measurements that were used in this study were carried out in mid to late 2009. And the field program to ground-truth the roof albedo took place in 2012. These dates help show the slow movement of the energy efficiency program to incentivize cool roofs and demonstrate that by the time the multi-band radiation data was collected, the full effects of the policy had not materialized (also, in part, due to the downturn in new construction). In addition, the ground-truth field measurements may not represent the original albedo improvements (in some cases, 3 years of aging should be taken into account). Staff commented in our draft final review conference call with the investigators on the need to define and explain "prescriptive performance" instead of prescriptive, as these are distinct terms of art within the cool community regulatory structure, and that counties, cities, and regions often adopt Energy Code and CalGreen standards as mandatory provisions, which complicates understanding the reach and effectiveness of

the Statewide cool community policy. The investigators agreed to a clearer statement of California cool roof and green building policy and to add a new recommendation section that details the effects of this study on the development of cool community policies at the state level and for local governments.

Staff also noted that the Cool Roof Rating Council has total and aged albedo properties for cool roof products sold in California and raised the question as to whether it was possible to conduct the field ground-truth study on the basis of total and aged albedo. The multi-band radiation data, however, does not directly correspond to total or aged albedo and field measurements had to replicate the multi-band data. A major product of the study is the database of the building shape files and roof albedo values for Los Angeles, Long Beach, Bakersfield, San Francisco, and San Jose. For the other two cities, a thousand shape file and roof albedo spreadsheet (representative of those cities) are available. Investigators agreed to highlight these resources as well as possible future link-up with the roof albedo website that LBNL has begun to run (a critical resource for local governments).

The results from this project – roof stock evaluations, individual roof albedos, and the base radiation database and methodologies developed for pavement albedo assessments – are critical inputs for future cool roof (and pavement) mitigation assessment simulations. The investigators have agreed to include language to this effect as part of the statewide cool community policy effects of the study in the new recommendation section.

IV. STAFF RECOMMENDATIONS

Staff recommends the Research Screening Committee accept this draft final report, subject to inclusion of appropriate additions and revisions in response to the staff comments and any changes and additions specified by the Committee.

DISCUSSION OF A DRAFT FINAL REPORT
ITEM NO.: IV.6
DATE: January 31, 2014
CONTRACT NO.: 10-313
Link to Report

STAFF EVALUATION OF A DRAFT FINAL REPORT

TITLE:	Understanding Primary Organic Aerosol Volatility at Atmospherically Realistic Concentrations for the SIP Analysis
CONTRACTOR:	University of California, Davis
PRINCIPAL INVESTIGATOR:	Michael J. Kleeman, Ph.D.
CONTRACT TYPE:	Interagency Agreement
BUDGET:	$309,769
CONTRACT TERM:	36 months

For further information, please contact Dr. Dongmin Luo at (916) 324-8496.

I. SUMMARY

Emissions tests have determined that primary organic aerosols (POA) generated from combustion sources behave like a series of semi-volatile compounds when the particulate phase concentrations range between 100 – 10,000 μg/m^3. More recent models fit to measurements of POA emitted from gasoline powered vehicles predict that POA is semi-volatile and will largely evaporate given sufficient time in the atmosphere. These conclusions are not supported by measurements of oxygenated organic species (carbonyls) emitted by gasoline vehicles. Hence, a follow-up study was needed to reconcile these differences. The objective of this project was to identify the dominant partitioning mechanism for POA emitted from gasoline- and diesel-powered vehicles at atmospherically realistic concentrations in the range from 5 to 30 μg/m^3. The results indicate that vehicles emit appreciable amounts of POA from fuel combustion that has very low volatility that can be characterized as effectively non-volatile under typical atmospheric conditions. The POA emitted during the cold-start portion of the driving cycle appears to have greater volatility than POA emitted during other phases of the driving cycle. These findings will have broad application within regional air quality

models used to evaluate the efficiency of emissions control programs on Particulate Matter (PM).

II. TECHNICAL SUMMARY

Objective

The objective of the proposed research is to identify the dominant partitioning mechanism for POA emitted from diesel- and gasoline-powered vehicles at atmospherically realistic concentrations in the range from 5 to 30 μg/m^3.

Background

Organic aerosols (OA) account for a significant fraction of fine particulate mass in the atmosphere. However, there are large uncertainties in evaluating the impacts of OA on atmospheric chemistry, climate, and human health, due to many unknowns regarding their sources, composition, properties, and transformation mechanisms. OA can be emitted directly from combustion sources (POA) or formed from gas species in the atmosphere (SOA). POA has been traditionally assumed to be non-volatile and non-reactive and thus distinctly separate from SOA although certain POA compounds have long been recognized as semi-volatile. Recently, the distinction between POA and SOA has become less clear because experiments have suggested that a significant fraction of POA can evaporate to the gas phase and then form SOA via atmospheric processing.

Limited emissions tests have determined that POA generated from combustion sources behaves like a series of semi-volatile compounds when the particulate phase concentrations range between 100 – 10,000 μg/m^3. The data available for atmospherically relevant concentrations below 30 μg/m^3 are sparse and the data below 10 μg/m^3 are missing entirely. The simple absorption theory that appears to explain the behavior of gas-particle distribution of condensable organics at high concentrations may not be accurate at atmospherically relevant concentrations. It is likely that other processes such as chemical and physical adsorption onto elemental carbon and/or partitioning into the aqueous phase play significant roles at lower concentrations.

Understanding of the gas-particle partitioning behavior of POA emissions from motor vehicles would be greatly improved by additional data describing concurrent gas- and particle-phase concentrations of individual POA species. In addition, the concurrent measurements of these POA species will also enable a direct evaluation of theoretical versus observed gas-particle partitioning for these species.

Project Summary

This research project explored the volatility of POA emitted from light duty gasoline-powered vehicles at atmospherically relevant concentrations using state of the science instrumentation. Emissions from a fleet of 8 gasoline vehicles operated on the University of California driving cycle were characterized by 1) thermal-optical measurements of filter-collected organic carbon and elemental carbon; 2**)** gas chromatography–mass spectrometry (GC-MS) analysis of denuder-filter-PUF samples; 3) high resolution Aerosol Mass Spectrometer (HR-AMS) measurements for organic mass and the bulk and elemental compositions of organic species; 4) Time-of-Flight Chemical Ionization Mass Spectrometer (ToF CIMS) measurements of gas-phase concentrations and elemental compositions of carbonyls, alcohols, ketones and organic acids; and 5) multi-wavelength photoacoustic spectrometer (PAS) measurements of BC. Vehicle exhaust was diluted to atmospherically relevant concentrations as different features of the dilution air were perturbed: temperature (25-100^{o}C), relative humidity (RH) (55-85 percent), and background BC particles concentrations (0-25 µg/m^{3}). Three main hypotheses were tested as a part of this research project.

1) The concentration of BC in the background dilution air changes the partitioning of individual organic compounds in the exhaust emitted from gasoline and diesel engines.

Result: This hypothesis is rejected because the action of BC was opposite to the expected trend based on simple adsorption theory of carbonyl species. BC added to the dilution air scavenged volatile organic carbon (VOC) precursors for carbonyl species which generally inhibited the production of individual carbonyl compounds in the exhaust. The original hypothesis was that the BC would draw more carbonyls into the condensed phase leading to increased concentrations. The opposite effect

happened - concentrations decreased because the BC scavenged the carbonyl precursors.

2) The relative humidity of the background dilution air changes the partitioning of individual organic compounds in the exhaust emitted from gasoline and diesel engines.

Result: The measurements made during the project are consistent with this hypothesis. Increasing relative humidity (RH) in the dilution air increased the total (i.e., gas and particle phase) emissions rate of carbonyl species by providing larger aqueous reaction volumes for carbonyl production. The net effect was an increase in carbonyl emissions rates in the particle phase.

3) The OA in motor vehicle exhaust does not behave like a completely semi-volatile material when comparing to a base-case derived from reasonable dilution factors so that concentrations are at atmospherically relevant levels (10-30 $\mu g/m^3$).

Result: The measurements made during the project are consistent with this hypothesis. Evidence suggests that POA emissions from light duty gasoline vehicles are composed of intermediate volatility (motor oil) and low volatility (fuel combustion products).

Overall, the results indicate that vehicles emit appreciable amounts (~75-80 percent) of POA from fuel combustion that has very low volatility that can be characterized as effectively non-volatile under typical atmospheric conditions. Real-time measurements show that the highest BC emissions occurred during the cold-start portion of the test and/or during periods of hard acceleration. The remaining fraction (~20-25 percent) of the particle phase emissions was POA that could be broadly classified as a semi-volatile material (similar to motor oil) or an effectively non-volatile material (hypothesized to be fuel combustion products). The POA emissions were generally more volatile during the cold start portion of the driving cycle and less volatile after the engine and exhaust system reached operating temperature.

The extrapolation of the single volatility distribution proposed by an earlier study to the ambient atmosphere will result in almost complete evaporation of POA emitted from motor vehicles. The result of the current study indicates the two component (fuel-derived + motor oil) volatility distribution more accurately predicts the volatility of POA emitted from light duty vehicles because it better captures the physical processes involved. This framework should be incorporated into future regional modeling applications that consider the volatility of POA. However, it is recommended that further vehicle test measurements are needed using the methodology developed in this report to develop fleet wide characterization of the emissions of both types of POA for use in future regional modeling applications.

III. STAFF COMMENTS

Staff from ARB's Air Quality Planning and Science, Monitoring and Laboratory, Mobile Source Operations**,** and Research Divisions reviewed an earlier version of the report and the current version has incorporated staff comments to improve its clarity. The final report accurately describes the completed work and its implications, and identifies future research needs. The reviewers' comments generally recognized the quality of the research effort and the practical importance of the results. The project successfully completed the stated objectives and the report does an excellent job of documenting the findings. In addition to preparing this final report, the investigators have published their results in two peer-reviewed journal and six additional papers are currently in preparation. The published papers were sent to the RSC members along with the draft final report. The investigator also prepared a test plan to help frame the discussion/coordination with other research team, which is appended to the UCD draft final report.

As indicated in this research project, understanding the chemical and physical properties of POA and the mechanisms that transform volatile and semi-volatile organic compounds into SOA is necessary for taking steps toward improving regional air quality models. The results will strengthen the scientific basis for the emissions controls within the State Implementation Plan.

IV. STAFF RECOMMENDATIONS

Staff recommends the Research Screening Committee accept this draft final report, subject to inclusion of appropriate additions and revisions in response to the staff comments and any changes and additions specified by the Committee.

DISCUSSION OF A DRAFT FINAL REPORT
ITEM NO.: IV.7
DATE: January 31, 2014
CONTRACT NO.: 09-333
Link to Report

STAFF EVALUATION OF A DRAFT FINAL REPORT

TITLE:	Three-Dimensional Measurements of Aerosol Mixing State during CalNex 2010 Using Aircraft Aerosol Time-Of-Flight Mass Spectrometry
CONTRACTOR:	University of California, San Diego
PRINCIPAL INVESTIGATOR:	Kimberly A. Prather, Ph.D.
CONTRACT TYPE:	Interagency Agreement
BUDGET:	$400,000
CONTRACT TERM:	48 months

For further information, please contact Dr. Eileen McCauley at (916) 323-1534.

I. SUMMARY

Aerosol properties have been characterized extensively using ground-based measurements in California. However, these measurements may not fully capture the spatial variations of aerosol properties both regionally and vertically, which are critically important as the aerosol climate effects are affected by the location of particles in the atmosphere. As part of the CalNex 2010 field campaign, an aerosol time-of-flight mass spectrometer (ATOFMS) was used to measure single particle aerosol chemical speciation and mixing state onboard the Twin Otter aircraft and the R/V Atlantis research ship. The extensive regional coverage provided by CalNex 2010 and some other aircraft campaigns allowed for unique and unprecedented insights into the variation of particle chemistry and sources in California. The results show that the majority of ambient carbonaceous particles in California were internally mixed and heavily influenced by secondary species that were most prevalent in the particular region. In general, there were significant spatial and temporal variations in aerosol properties and mixing states in the Ports of Los Angeles / Long Beach, the South Coast

Air Bain, and Northern California. The data provided important information to improve our understanding of the climate effects of aerosols in California.

II. TECHNICAL SUMMARY

Objective

The goal of this project is to obtain detailed data on aerosol size, chemical speciation, and mixing state during the CalNex 2010 campaign and link it with measured optical and hygroscopic properties on board a Twin Otter aircraft and along the California coast on board a National Oceanic and Atmospheric Administration (NOAA) ship to better understand the major aerosol sources and their effects on air quality and climate change in California.

Background

Particles in the atmosphere impact human health and climate. Knowledge of the sources of these aerosol particles, as well as how their physiochemical properties evolve once emitted, is key to accurately predicting their impacts. Numerous studies over the last decade have utilized ground-based measurements to characterize aerosol chemical composition in California. However these measurements may not fully capture the spatial variations of aerosol sources and processes, both regionally and vertically. These differences are critically important as the calculation of climate effects generally rely on the positioning of the aerosol regionally and in the atmospheric column. Properties such as radiative forcing and cloud activity (formation, modification, disintegration) need spatial resolution to be calculated accurately. The CalNex 2010 field campaign was undertaken to elucidate the links between aerosols, air pollution, and climate in order to provide insights to policy makers. As part of this study, real-time, single particle mixing state aircraft and shipboard measurements were made. The extensive regional coverage provided by these studies allowed for unique insights into the variation of particle chemistry and sources in California.

Project Summary

This project exploited the large regional coverage provided by aircraft and ship-based measurements as part of the CalNex 2010 campaign and the unique single particle

ATOFMS to investigate the spatial (horizontal and vertical) variability in aerosol chemical composition. Specifically, the measurement data was used to answer:

1) What are the major sources contributing to black carbon or soot aerosols in California?
2) Do differences exist in sources and chemistry between northern and southern California?
3) Do differences exist in chemical mixing state throughout the LA basin?
4) How accurate are the optical retrievals from satellite measurements?
5) What is the vertical profile of chemical mixing state within and just above the boundary layer?
6) What are the relationships between chemical mixing state and hygroscopic properties?

The ship-based measurements sampled coastal waters from Los Angeles to Sacramento. In the Ports of Los Angeles / Long Beach area, particles containing soot made up the largest fraction of submicron particles while organic carbon particles comprised the largest fraction of submicron number concentrations in Northern California. The mixing state of these carbonaceous particle types varied during the cruise with sulfate being more prevalent on soot-containing particles in Southern California coastal area due to the influence of fresh shipping and port emissions in addition to contributions from marine biogenic emissions. Contributions from secondary organic aerosol species, including amines, and nitrate were more prevalent in Northern California, as well as during time periods impacted by agricultural emissions. These regional differences and changes in the mixing state and sources of particles have implications for heterogeneous reactivity, water uptake, and cloud-nucleating abilities of aerosols in California.

The CalNex 2010 and Carbonaceous Aerosol and Radiative Effects Study (CARES) aircraft campaigns were used collectively to provide aerosol mixing state measurements over large regions of Northern and Southern California. The results suggest that most submicron particles sampled by the ATOFMS contained carbonaceous material, and a majority of them showed signs of atmospheric aging. Particles were internally mixed

with secondary species, including sulfate, nitrate, methanesulfonic acid (MSA), organosulfate (OS), and ammonium. Single particle peak ratios show that there was large heterogeneity of the mixing state in Southern California; meaning that a significant number of particles were mixed with high amounts of nitrate as well as sulfate, while in Northern California there was a significantly higher fraction of organic carbon mixed with sulfate. The contributions of soot and OC to single particle mixing state were found to also vary greatly depending upon the region, with soot having a larger influence in the south and OC being more prevalent in the north. However, during the time period when PM2.5 concentrations were relatively higher in Northern California, particle mixing states were similar to Southern California, indicating that both spatial and temporal changes in mixing state will need to be taken into account for accurate regional aerosol-climate modeling

Regional analysis of aircraft data indicates very different particulate chemistry depending upon the area of the LA Basin being sampled. Near Long Beach, particle chemistry was significantly influenced by port emissions, as evidenced by increased fractions of soot and soot-OC particles. In addition, the secondary species associated with these particles differed from particles measured in the rest of CalNex, containing higher peak ratios of sulfate compared to nitrate. These results agree with ship-based measurements in the same region and explain the discrepancy between these measurements. The chemically resolved vertical profile of CalNex data shows higher number fractions of soot at lower altitudes, while particles at altitudes closer to the top of the boundary layer were more highly processed, indicating that particles may acquire significant amounts of sulfate and nitrate coatings as they rise in altitude. ATOFMS measurements in combination with in flight hygroscopicity measurements uncovered that biomass burning aerosol may be active cloud condensation nuclei, but relatively non-hygroscopic at sub-saturated relative humidity. The similar hygroscopic characteristics occurred on non-biomass burning influenced periods as well. This could be due to the presence of an organic coating with variable water uptake depending on sub- or super-saturated conditions.

A better understanding of the relationship between the spectral aerosol optical properties and the size and chemical composition of aerosols can help to improve our

estimation of the aerosol radiative forcing. In this study, ATOFMS data from several flight campaigns was used to develop a methodology and determine its limitations to estimate absorbing aerosol speciation from spectral optical measurements. Results from this study indicate a dominance of mixed types in the classification leading to an underestimation of the primary sources. Secondary species were better classified, but the separation between fossil fuel and biomass burning aerosols has limitations because of the similarity of the optical properties. These results helped to improve the classification procedure for aerosol compositions based on optical properties, but suggested that this technique should be used with the limitations taken into account.

Overall, this CalNex 2010 project was a significant enhancement to efforts in characterizing the spatial and temporal variations of aerosol chemical speciation and mixing state. It provided important data and information for better estimating the effects of particles on climate in California.

III. STAFF COMMENTS

Staff from ARB's Air Quality Planning and Science and Research Divisions, the South Coast Air Quality Management District (SCAQMD), and NOAA reviewed an earlier draft. Some major general and specific comments and suggested revisions/edits were received from the reviewers, and sent back to the PI. Staff also discussed with the PI on some important issues related to the revision of the DFR, such as the reformation and reorganization of the text, additional discussion of the vertical variation of aerosol properties, some more clarification of the difference between ATOFMS data and the standard PM2.5 mass and speciation measurements, the inclusion of supplemental materials in the report, etc. Staff from ARB's Research Division reviewed the revised draft report again and provided additional comments to the PI for further improvement of the report. Staff generally believes that the PI took significant efforts to revise the report, and added additional discussions/descriptions to address the major issues/concerns raised by the reviewers. With these revisions, the DFR was greatly improved, although staff does have a few additional minor comments on the revised report provided to the Committee that will need to be addressed before the report is finalized. Overall, the results described in this report accomplished the major objectives stated in the proposal, although the lack of high altitude measurements of the Twin Otter aircraft

during the CalNex 2010 limited the ability of this study to address some specific questions outlined in the original proposal. The report did provide some suggestions on future studies to further understand the vertical distributions of aerosol properties including mixing states and the sources of particles at different vertical layers. Six peer-reviewed scientific publications to date have used this dataset, highlighting that the results from the ATOFMS played an important role in improving our understanding of the sources of carbonaceous aerosols and their effects on climate in California.

IV. STAFF RECOMMENDATIONS

Staff recommends the Research Screening Committee accept this draft final report, subject to inclusion of appropriate additions and revisions in response to the staff comments and any changes and additions specified by the Committee.

DISCUSSION OF A DRAFT FINAL REPORT
ITEM NO.: IV.8
DATE: January 31, 2014
CONTRACT NO.: 10-305
Link to Report

STAFF EVALUATION OF A DRAFT FINAL REPORT

TITLE:	Extended Analysis of the CARES Aerosol Chemistry Data to Characterize Sources and Processes of Organic Aerosol in the Sacramento Valley of California
CONTRACTOR:	University of California, Davis
PRINCIPAL INVESTIGATOR:	Qi Zhang, Ph.D.
CONTRACT TYPE:	Interagency Agreement
BUDGET:	$155,000
CONTRACT TERM:	36 months

For further information, please contact Dr. Eileen McCauley at (916) 323-1534.

I. SUMMARY

Particles less than 2.5 microns in diameter have serious adverse impacts on human health and play an important role in climate forcing, visibility degradation and deposition to ecosystems and crops. Although a significant fraction of these submicron aerosols are comprised of OA - typically 30 to 80 percent of the mass fraction - the sources and composition of this OA in California are highly uncertain. This project investigated the composition, sources, and processes of submicrometer particles in northern California by means of integrated analyses of measurements that were taken during the CARES in the Sacramento and western Sierra Foothills area in 2010. Measurements from a high-resolution time-of-flight aerosol mass spectrometer (HR-ToF-AMS), which provides size-resolved chemical composition of aerosols in real time, formed a critical element in the study. Results from the analyses include: the growth of new particles was driven primarily by condensation of oxygenated organic species; bulk composition of the ultrafine mode organics during new particle events was similar to SOA observed in transported urban plumes; and new particle events over Sacramento and Sierra-Nevada regions are promoted by the interaction between biogenic emissions and

urban plumes. The data and analysis results from this work help constrain SOA formation mechanisms and indicate aerosol processes that are not currently treated in models.

II. TECHNICAL SUMMARY

Objective

The proposed research has several objectives:

1) Analyze HR-ToF-AMS data that was collected in Northern California to determine ratios of elements (carbon, oxygen, nitrogen, hydrogen) and the temporal and temperature-dependent variation of the bulk composition of OA.
2) Perform multivariate analysis of the HR-ToF-AMS data to determine components of OA and their associations with distinct sources, physicochemical properties, and atmospheric processes.
3) Conduct focused case studies of SOA formation and new particle formation and growth processes utilizing the HR-ToF-AMS data in conjunction with concurrent measurements of gaseous precursors and meteorology.

Background

Aerosols are ubiquitous in the atmosphere and directly affect human health, climate, and deposition to ecosystems and crops. OA typically account for 30-80 percent of the total submicron particle mass fraction worldwide. Despite this importance, OA represent a challenge to characterize and model due to the thousands of distinct compounds with vastly different properties (such as oxidation degree, volatility, and hygroscopicity) which comprise it. In addition, primary source strengths and atmospheric evolution of OA and its gaseous phase precursors remain poorly understood. As a consequence of this gap in knowledge, most current regional air quality models significantly under predict OA mass.

Among developments in aerosol instruments, Aerodyne Aerosol Mass Spectrometers (AMS) are unique in providing real-time, quantitative, and size-resolved information on submicron non-refractory aerosol chemistry. The High Resolution-ToF-AMS is further able to determine the elemental ratios and oxidation degrees of organic species within OA. Various versions of the AMS have been deployed in numerous field campaigns

throughout the world, though only a few have been conducted in California; among these are ARB and NOAA-sponsored CalNex 2010 studies in Los Angeles and the San Joaquin Valley.

One of the most comprehensive AMS datasets for northern California was acquired as part of DOE-funded CARES campaign in 2010. This dataset includes measurements from a HR-ToF-AMS and a Scanning Mobility Particle Sizer (SMPS) at a site in Cool, California, which is downwind of Sacramento. The Atmospheric Science Program of DOE funded the deployment of the instruments at Cool and the initial analysis of the dataset for size-resolved chemical composition and temporal variations of sulfate, nitrate, ammonium, chloride, and total organics. This project leveraged this previous work by using the existing dataset for in-depth studies of the sources and processes of submicrometer particles over the Sierra foothills region.

Project Summary

The focus of the project was on the chemistry, physical properties, and diurnal and temporal variations of aerosols at Cool (denoted as the T1 site of the project), which is located at the foothills of the Sierra Nevada Mountains. In the area around the site, intense biogenic emissions are periodically mixed with urban outflow from the Sacramento metropolitan area that has been transported by daytime southwesterly winds.

During the sampling campaign, the average mass loading of submicrometer particles (PM_1) was 3.0 µg m^{-3}, and was dominated by organics (80 percent) and sulfate (9.9 percent). OA had a nominal formula of $C_1H_{1.38}N_{0.004}O_{0.44}$, and thus an average organic mass-to-carbon (OM/OC) ratio of 1.70. Two distinct oxygenated OA factors were identified using positive matrix factorization of the high-resolution mass spectra of organics. The more oxidized component, denoted MO-OOA, had an oxygen to carbon molar ratio O/C = 0.54, and was interpreted as a surrogate for SOA influenced by biogenic emissions. The less oxidized component, denoted LO-OOA, had O/C = 0.42, and was identified as SOA formed in photochemically processed urban emissions. A third OA factor was also identified – a hydrocarbon-like OA (HOA) factor; this component was interpreted as primary emissions largely due to local traffic. On

average, SOA (which was taken as the sum MO-OOA + LO-OOA), accounted for 91 percent of the total OA mass and 72 percent of the PM_1 mass observed at Cool.

The production of SOA varied greatly during the study as indicated by large changes in the ratio of OA mass to carbon monoxide, CO, ($\Delta OA/\Delta CO$), which spanned the range of 5-196 $\mu g/m^3$/ppm. The highest $\Delta OA/\Delta CO$ ratio, 97 $\mu g/m^3$/ppm on average, was attained in air masses that were dominated by anthropogenic emissions in the presence of a high concentration of biogenic volatile organic compounds (BVOCs). Much lower ratios were observed when urban plumes arrived in a low BVOC environment or during other periods dominated by biogenic SOA. These results demonstrate that SOA formation is enhanced when anthropogenic emissions interact with biogenic precursors.

Regional new particle formation and growth events (NPE) were also observed on most days over the Sacramento and western Sierra Foothills areas. Simultaneous particle measurements at both the T0 (Sacramento, urban site) and T1 sites of CARES indicate that the NPE usually occurred in the morning with the appearance of an ultrafine mode followed by the growth of this mode to ~50 nm in the afternoon. These events were generally associated with southwesterly winds bringing urban plumes from Sacramento to the T1 site. Analysis of AMS data indicates that the growth of new particles was driven primarily by the condensation of oxygenated organic species and, to a lesser extent, ammonium sulfate. More specifically, during NPE the bulk composition of ultrafine mode organics was very similar to that of anthropogenically-influenced secondary OA (observed in transported urban plumes) and concentrations of species representative of urban emissions (e.g. BC, CO) were significantly higher compared with non-event days; these results indicate that the frequently occurring NPE over the Sacramento and Sierra-Nevada regions were promoted by the interaction between biogenic emissions and urban plumes.

III. STAFF COMMENTS

Staff from ARB's Air Quality Planning and Science and Research Divisions reviewed the draft final report and are very satisfied with the quality of work performed. The research contributes much to our understanding of the composition and evolution or organic aerosols in Northern California, and specifically, of how urban plumes interact with

biogenic emissions in particle growth and new particle formation events. The report synthesizes and translates the results from this research into data products and formulations that may be directly used to inform and evaluate air quality models.

Two final items that need to be addressed are the inclusion of an Executive Summary and addition of a data file. The current, overly long Abstract should be pruned to approximately 200 words and an Executive Summary added in a revised report. The question of which data sets to include in a separate file requires consideration, because raw data from the AMS typically requires dedicated storage drives and is interpretable only by researchers with extensive training in AMS data analysis methods. Staff believes the most useful data products would be processed sets that contain factor analysis results, aerosol size distributions, and collocated measurements (gas phase species and meteorological parameters). A final list of data set products will be developed by staff.

IV. STAFF RECOMMENDATIONS

Staff recommends the Research Screening Committee accept this draft final report, subject to inclusion of appropriate additions and revisions in response to the staff comments and any changes and additions specified by the Committee.

DISCUSSION OF A DRAFT FINAL REPORT
ITEM NO.: IV.9
DATE: January 31, 2014
CONTRACT NO.: 09-317
Link to Report

STAFF EVALUATION OF A DRAFT FINAL REPORT

TITLE:	AMAX-DOAS Trace Gas Column Observations from Research Aircraft over California
CONTRACTOR:	University of Colorado, Boulder
PRINCIPAL INVESTIGATOR:	Rainer Volkamer, Ph.D.
CONTRACT TYPE:	Standard Agreement
BUDGET:	$549,999
CONTRACT TERM:	48 months

For further information, please contact Dr. Eileen McCauley at (916) 323-1534.

I. SUMMARY

Assessments of atmospheric chemical models and emissions inventories are based largely on measurements from ARB's monitoring network, which are confined to a limited number of surface stations. To overcome these spatial restrictions, a University of Colorado Multi-Axis Differential Optical Absorption Spectrometer (CU AMAX-DOAS) was deployed on the National Oceanic and Atmospheric Administration (NOAA) Optical Remote Sensing Twin Otter research aircraft as part of the CalNex field campaign over California in the summer of 2010. Comprehensive observation maps were made for horizontal and vertical distributions of the pollutants nitrogen dioxide (NO_2), formaldehyde (HCHO), and glyoxal (CHOCHO) over much of the SoCAB, SJV, and Northern California (Bay Area to Sierra foothills). Based on these measurements, extensive comparisons and analyses were carried out and include: comparisons with ground based and satellite (NASA OMI) measurements, weekend/weekday studies of ozone in SoCAB, quantification of NO_X emissions and O_X production regions and rates, comparisons with NO_X emissions inventories, and studies of constraints imposed by HCHO and CHOCHO on oxidative capacity in models. Measurement products from this project will be used to improve air quality models for photochemical production of ozone

and aerosols, and thus improve ARB's abilities to strategically target mitigation efforts for air quality and climate change.

II. TECHNICAL SUMMARY

Objective

The objective of this project is to deploy the CU AMAXDOAS on the NOAA Optical Remote Sensing Twin Otter research aircraft during and immediately after the CalNex field campaign in 2010. The AMAXDOAS will measure pollutant concentrations in and above the boundary layer, probing directly the horizontal and vertical distributions of NO_2, formaldehyde, oxygen dimers (O_4) and glyoxal over the SoCAB, SJV, Northern California and ocean. The measurement results will be used to test and constrain atmospheric models, assess/validate satellite measurements, and provide improvements for models and validated satellite data for better management of air resources.

Background

This project utilized a research aircraft to deploy an Airborne Multi AXis DOAS instrument, which measures horizontal and vertical distributions of the pollutants: NO_2, an ozone precursor and radical sink; formaldehyde, a carcinogen and a radical source; and glyoxal, an indicator for the rate of VOC oxidation and precursor for SOA. Column integrals of these gases and ozone were mapped over much of California. These observations along with ground and satellite based measurements provided a rich data set for subsequent analyses and testing of atmospheric models.

Project Summary

Key findings from this project include:

- The comprehensive mapping of horizontal distributions of NO_2 vertical column densities (VCD, concentration integral over height below the aircraft) over many regions in California has provided over 18,000 NO_2 VCD measurements. A total of 52 flights were carried out with the NOAA Twin Otter research aircraft during May 19, 2010 – July 18, 2010.
- The NO_2 data provides updates for NO_X emissions in the CARB 2010 emission inventory. Though, NO_2 vertical column densities compare within 30 percent with

predictions based on the CARB 2010 emission inventory, there is a mismatch in the location where these emissions occur.

- The distribution of NO_2 is layered and varies strongly up to altitudes of several kilometers.
- Comparison of NO_2 VCD measurements with coincident VCDs measured by satellite OMI (NASA's NO_2 product) show very good agreement (within 5 percent), suggesting that satellites can provide useful data to manage air resources over California during summer months. It was also concluded that good agreement applies only over areas with high surface albedo, like SoCAB during summer, and does not necessarily extrapolate globally.
- Significant emissions from oil and natural gas production are missing in the emission inventory for the Bakersfield area. A case study near Bakersfield quantified O_3 production rates using the divergence flux approach, and concluded that emissions from oil and natural gas production can lead to higher O_3 production rates than urban emissions.
- In the South Coast Air Basin (SoCAB), O_3 chemistry appears to be on the verge of transitioning to the NO_X limited regime during very hot days. Further reductions in NO_X in the future are likely to result in lower O_3 levels under such scenarios.
- This project developed new tools to measure mobile oxygenated volatile organic compounds (OVOC) formaldehyde and glyoxal, which are the first such measurements from aircraft.
- The ratio of glyoxal to formaldehyde, RGF (CHOCHO/HCHO VCD) was shown to be a useful metric to distinguish anthropogenic vs. biogenic VOC influences in an air masses.
- Comparisons between HCHO and CHOCHO measurements and predictions from different atmospheric models show that models consistently and significantly under predict the OVOC concentrations, and indicate missing VOC sources, or existing shortcomings in the VOC chemistry that are expected to impact oxidative capacity and SOA formation rates.
- Vertical distributions over inland locations show significant presence of elevated HCHO and CHOCHO between 1 – 2 km altitude, which is not predicted well by several models. The origin of this discrepancy is currently not understood.

III. STAFF COMMENTS

Staff from the Air Quality Planning and Science and Research Divisions reviewed this draft final report, as well as previous drafts of all the papers which form the main body of the report, and are very satisfied with the presentation, synthesis, and analysis of measurements.

An unresolved issue is that of final data products for the ARB. As raw data from AMAX-DOAS requires extensive analysis to retrieve useable data products, staff believes the most useful data sets would be processed height-resolved concentrations and column densities for the flights that were analyzed. In addition, corresponding O_3 LIDAR, ground based VOC and meteorological parameter measurements should be provided.

Several relatively minor comments on formatting issues (e.g. removal of line numbers and watermarks) and clarification concerns were received from ARB staff; these will be incorporated into the final report.

IV. STAFF RECOMMENDATIONS

Staff recommends the Research Screening Committee accept this draft final report, subject to inclusion of appropriate additions and revisions in response to the staff comments and any changes and additions specified by the Committee.

DISCUSSION OF A DRAFT FINAL REPORT
ITEM NO.: IV.10
DATE: January 31, 2014
CONTRACT NO.: 10-326
Link to Report

STAFF EVALUATION OF A DRAFT FINAL REPORT

TITLE:	Synthesis of Policy Relevant Findings from the CalNex 2010 Field Study
CONTRACTOR:	National Oceanic and Atmospheric Administration
PRINCIPAL INVESTIGATORS:	David Parrish, Ph.D. Joost de Gouw, Ph.D.
CONTRACT TYPE:	Standard Agreement
BUDGET:	$252,378
CONTRACT TERM:	36 months

For further information, please contact Dr. Eileen McCauley at (916) 323-1534.

I. SUMMARY

Ozone and PM2.5 air quality in the South Coast Air Basin (SoCAB) and San Joaquin Valley Air Basin (SJVAB) continue to be among the worst in the nation, with slower than desired rates of improvement. A major field study (Research at the Nexus of Air Quality and Climate Change, aka CalNex 2010) was conducted in the early summer of 2010 to investigate the factors contributing to the poor air quality and the strategic relationships between the air quality and climate change emission control programs. ARB contracted with NOAA to prepare a report synthesizing the primary results and findings coming out of the CalNex study. Some of the more significant findings coming out of CalNex that have regulatory or policy implications include the following:

1) SOA and background O_3 comprise a significant portion of ambient PM2.5 and O_3 concentrations and may impact the focus and amount of emission reductions needed to attain ambient air quality standards.
2) California's focus on reducing NO_X emissions has reduced both ozone and PM concentrations.

3) Improvements are still needed in the current emissions inventory (e.g., unidentified VOC source in the San Joaquin Valley, methane and N_2O underestimated).
4) Improvements are still needed in air quality forecasting and modeling.
5) Biogenic emissions combine with anthropogenic emissions in the SJVAB to create significant amounts of SOA, even during the night.
6) Not all emission control efforts will be “win-win” from both air quality and climate change perspectives.

II. TECHNICAL SUMMARY

Objective

The primary objectives of this project were to synthesize the scientific findings of CalNex2010 researchers, to conduct additional integrative data analyses, and to present relevant results and findings in a format that assists policy-makers as they formulate California’s response to the inter-related issues of air quality and climate change.

Background

NOAA and ARB collaborated to plan and lead the CalNex 2010 field study in California, with fieldwork beginning in May and ending in July of 2010. CalNex 2010 was a collaborative, multi-agency, intensive climate and air quality field study that is providing scientific information on climate and air quality issues that can be used to guide the development of cost-effective policies that maximize the societal benefits with regard to both issues. The study was planned to broadly address Science Questions relevant to the air quality community in six general areas: meteorological representativeness of the study period, pollutant emissions, chemical transformations and climate processes, transport, modeling and forecasting skills, and pollutants that participate in both air quality and climate considerations. Although researchers are still analyzing the data and publishing results, the bulk of the data analysis has been completed and published (>90 so far) in peer-reviewed journals.

Project Summary

The CalNex2010 field study was conducted throughout California (but primarily in the SoCAB and the SJVAB) during May, June, and July of 2010. The primary objective was to address scientific questions/issues simultaneously relevant to atmospheric pollution and climate change. Measurements from a network of ground sites, a research ship, tall towers, balloon-borne ozonesondes, multiple aircraft, and satellites provided *in situ* and remotely sensed data on trace pollutant and GHG concentrations, aerosol chemical composition and microphysical properties, cloud microphysics, and meteorological parameters.

The CalNex 2010 field study was initially planned with 12 broad research questions that were developed to guide the data collection and analysis efforts. These general questions were later refined to 23 specific questions by ARB and NOAA staff to directly address technical issues in which policy-makers are often interested. For example, “You have collected a lot of detailed information for these locations and time periods; how representative (applicable) are your results (findings) to other areas or times of the year?”

The contractor worked with ARB staff from the Research and the Air Quality Planning and Science Divisions to ensure that NOAA’s analyses and summaries of the study participants’ investigations would address the ARB’s needs and concerns. The contractor conducted additional analyses to address some questions not being answered by other investigators. The contractor regularly participated in data analysis conferences and met with ARB staff and management to be aware of the ARB’s needs for information, if not answers.

The contractor closely tracked the research efforts and the planned publications by all CalNex 2010 participants. The status of the papers, including links to the ones that have been published can be found on the internet at http://tinyurl.com/CalNex-papers. The papers are organized by general topic areas: Synthesis papers, Emission and Inventory papers, Atmospheric Chemistry and Transport papers, and Aerosol papers. A link is also provided to the US Department of Energy project, CARES, which overlapped

temporally with CalNex and included several complementary measurements. As of December 1, there were 93 CalNex 2010 research papers that had been either published, accepted for publication, or undergoing peer review. There are more than 30 additional manuscripts being prepared for eventual publication. NOAA is also maintaining a CalNex2010 field study webpage where many details and the data collected during the field study can be accessed (http://www.esrl.noaa.gov/csd/projects/calnex/). Data from the CalNex 2010 ground site in Bakersfield are available by contacting Leon Dolislager (ldolisla@arb.ca.gov).

Some of the more significant findings coming out of the CalNex 2010 research thus far include: 1) the differences between pollution chemistry in the SJVAB and the SoCAB; 2) the role of nighttime chemistry in SOA formation, particularly in the SJVAB; 3) the general effectiveness of NO_X controls and ocean-going vessel regulations; 4) the deficiencies in the emissions inventory (e.g., methane, nitrous oxide, and ammonia are underestimated) and in forecasting & modeling tools (e.g., "persistence" forecasting performs as well); 5) the significant roles of SOA formation and ozone transport on ambient conditions in California; 6) the implication of an as yet unidentified, temperature-dependent VOC source in the SJVAB; and 7) that the motor vehicle emissions control program has been very effective, reducing various pollutants by ~98 percent over the last five decades (although motor vehicles still remain the primary source of air pollutants to which people are exposed).

III. STAFF COMMENTS

Staff of NOAA has conducted data analyses and synthesized CalNex 2010 results from other researchers to date in this report. An Appendix is also provided to document all the measurements during the study. Additional analyses of observations and modeling studies are underway that should extend, improve, and in some cases perhaps contradict these results. The findings published thus far already illustrate the continuing scientific and regulatory value of short-term intensive field studies, even in well-studied but diverse regions such as the SJV and the SoCAB. Several of the CalNex 2010 analyses depended critically on data collected by previous studies as well as the long-term monitoring network. Intensive field studies like CalNex 2010 are necessary

from time to time to collect the detailed chemical measurements of pollution over broad areas and aloft where the routine monitoring information is limited or non-existent. Together, the occasional intensive special studies and long-term routine monitoring allow air pollution scientists to: 1) more confidently characterize emissions; and 2) improve our understanding of the sources and processes affecting ozone and particulate matter concentrations in California's air in order to develop integrated emission control strategies that are as effective and efficient as possible.

The contractor has submitted multiple sections of the report as it was being prepared for review, comments, and suggestions by the contract manager and staff of the Air Quality Planning and Science Division. The draft final report was distributed more broadly for input by additional ARB staff (multiple divisions), by local air quality district staff that work within the air basins of primary focus for CalNex (i.e., SoCAB and SJVAB), and by many of the collaborators in the CalNex field study to ensure that their research and implications were accurately summarized and characterized.

Staff is pleased with the efforts that Dr. Parrish made to visit, consult with, coordinate with, and inform not only ARB staff on several occasions but also with the CalNex and CARES collaborators. Staff is satisfied with the content and quality of the draft final report and only has relatively minor comments and suggestions. Staff has concerns about the content and implications of some of the published papers but that is not something the contractor can address.

The major changes desired in the final report include:

- The inclusion of the general topic areas within the 23 Responses to Questions to provide the reader with additional context of the discussions.
- Some editorial rephrasing to decrease the chances of readers misinterpreting a finding (e.g., the effectiveness of NO_X controls in the SJV; the magnitude of the transport of San Francisco Bay Area (SFBA) emissions offshore to southern California; the reduction (not cessation) of rice residue burning; reconciliation of different seasonal patterns in PM2.5 concentrations from different sampling networks (e.g., STN/CSN, IMPROVE, SLAMS/NAMS), etc.).

- The inclusion of some “win-win” control scenarios (hopefully coming out of CalNex) such as O_3 reductions, fuel efficiency standards, diesel truck regulations).
- Fixing some links to the web that did not work.
- Redrafting the discussion under Finding I2b as the material did not support the finding.
- The addition of a final section that articulates some of the operational lessons learned from CalNex and recommendations for future research (e.g., What operational lessons were learned from conducting the CalNex field study? In what topics or areas should researchers focus, both with analyzing the CalNex data and conducting field studies in the future?).

IV. STAFF RECOMMENDATIONS

Staff recommends the Research Screening Committee accept this draft final report, subject to inclusion of appropriate additions and revisions in response to the staff comments and to any changes and additions specified by the Committee.

DISCUSSION OF A DRAFT FINAL REPORT
ITEM NO.: IV.11
DATE: January 31, 2014
CONTRACT NO.: 10-309
Link to Report

STAFF EVALUATION OF A DRAFT FINAL REPORT

TITLE:	Calibrating, Validating, and Implementing Process Models for California Agriculture Greenhouse Gas Emissions
CONTRACTOR:	University of New Hampshire
PRINCIPAL INVESTIGATOR:	Changsheng Li, Ph.D.
CONTRACT TYPE:	Standard Agreement
BUDGET:	$249,688
CONTRACT TERM:	36 months

For further information, please contact Dr. Dongmin Luo at (916) 324-8496.

I. SUMMARY

Agricultural soils are an important source of GHGs that are responsible for global warming. Because production of GHGs such as nitrous oxide (N_2O) and methane (CH_4) in soil is driven by microbial activities, the emission fluxes of these gases, being affected by numerous environmental factors, are extremely variable both spatially and temporally. The current California inventory of N_2O from agricultural soils is developed using default emission factors derived from global averages. An alternative approach, recommended by the Intergovernmental Panel for Climate Change (IPCC) and adopted by the U.S. Environmental Protection Agency, is to use process-based modeling which accounts for environmental and management variables. This project developed a California-specific process-based DeCompoistion-DeNitrification (DNDC) modeling tool that incorporates California soil, crop, and management practice information for estimating N_2O emissions from California agricultural soils. It was estimated that, based on the modeling package, California agricultural soils contributed 3.50 metric million tonne CO_2 equivalent (MMT CO_2E) of N_2O emissions which is lower, but within the uncertainty range of the current N_2O inventory. The modeling tool along with its

associated database provided ARB the capability of producing detailed N_2O maps based on prevalent agricultural land use and management practices, and can be used to develop future N_2O inventory from agricultural soils for mitigation efforts.

II. TECHNICAL SUMMARY

Objective

The objective of this project was to develop, demonstrate, and deploy a process-based spatial modeling tool for simulating N_2O emissions from agricultural soils in California.

Background

Emission of N_2O and CH_4 from agricultural soils is part of the natural nitrogen and carbon cycling processes, driven by soil microbial activities. Due to variation of environmental conditions that affect soil microbial activities, the emission fluxes of N_2O and CH_4 are highly dynamic both spatially and temporally. Extensive field investigations have been conducted to characterize N_2O emissions from a wide range of cropping systems in California. These field studies were generally isolated tests. Use of process-based modeling such as DNDC is an effective way to integrate the field results providing a comprehensive emission estimation apparatus for statewide emission inventory development for California.

The DNDC model is a process-based geochemical model developed to simulate carbon and nitrogen speciation and interactions in agro-ecosystems. The model has been used extensively to predict CH_4 and N_2O emissions and soil carbon sequestration in agro-ecosystems and was selected by the American Carbon Registry as the industry standard methodology for carbon registry from agricultural land. DNDC has successfully predicted CH_4 and N_2O emissions for selected crops at the field scale.

Project Summary

This project compiled California-specific information on soil, crop, climate, and management practices and field measurements of GHG emissions; conducted model calibration, validation, and comparisons; performed emission simulations; and provided the modeling tool and training to ARB users.

To simulate N_2O emissions from California agricultural soils using DNDC, the project first developed statewide spatial databases of California soil, agricultural land use, meteorology, and prevalent management practices. This information provided basic inputs, through Geographic Information System (GIS) interface, to the DNDC model.

The measured 40 datasets including crop growth characteristics and daily N_2O emission fluxes, for vineyard, almond, tomato, wheat, corn, sunflowers, beans, and alfalfa, were then used to calibrate and validate the DNDC model to ensure that the overall carbon and nitrogen dynamics of the tested cropping systems were correctly represented. For comparison purpose, a subset of the field data (25 out of 40) was also used to evaluate another lead model DayCent, due to its limited capacity in simulating perennial crops and the drip irrigation.

The performance of the models in predicting N_2O fluxes was evaluated by comparing between the field measured and model simulated daily fluxes. It is found that, with exponential interpolation assuming a daily flux change of 0.8 fraction upwards or downwards between measurement dates, DNDC was able to predict the measured annual emission rates of N_2O very well (R^2=0.79), outperforming DayCent which had no significance level (R^2=0.005). The results also suggested that linear interpolation may be inappropriate for both DNDC and DayCent simulations.

Regional simulation was conducted by linking DNDC to a GIS database which contains all the environmental and management variables. The estimated annual emission rate of 3.50 MMT CO_2E for California agricultural soils is comparable to the current California inventory of 3.66 MMT CO_2E.

In addition, the major product which is a modeling tool package with current version of DNDC and California specific soil and crop database has been provided to ARB. The package includes spreadsheet tools and scripts for easy updating of environmental and management inputs and the model interface allows users to conduct site or regional simulations for inventory or mitigation studies.

III. STAFF COMMENTS

An earlier version of the draft final report was distributed to a large group of stakeholders for review, including representatives from growers, research institutes, and federal, state and local environmental agencies. The Principal Investigator addressed the reviewers' comments and revised the report accordingly. Since then, staff provided additional comments, requesting incorporation of crop rotation data into the modeling tool, ranking of crops with emission potentials, and discussion of other GHGs from soil (e.g., methane). The Principal Investigator has agreed to address them in the final products of the contract. Staff of Air Quality Planning and Science Division also participated in the modeling tool demonstration and expressed positive feedback about the robust of the tool in deriving California statewide N_2O emissions from agricultural soils.

IV. STAFF RECOMMENDATIONS

Staff recommends the Research Screening Committee accept this draft final report, subject to inclusion of appropriate additions and revisions in response to the staff comments and any changes and additions specified by the Committee.

DISCUSSION OF A DRAFT FINAL REPORT
ITEM NO.: IV.12
DATE: January 31, 2014
CONTRACT NO.: 09-346
Link to Report

STAFF EVALUATION OF A DRAFT FINAL REPORT

TITLE:	Modeling Optimal Transition Pathways to a Low Carbon Fuel Economy in California
CONTRACTOR:	University of California, Davis
PRINCIPAL INVESTIGATOR:	Sonia Yeh
CONTRACT TYPE:	Interagency Agreement
BUDGET:	$278,356
CONTRACT TERM:	48 months

For further information, please contact Fereidun Feizollahi at (916) 323-1509.

I. SUMMARY

Achieving the 2050 target of greenhouse gas (GHG) emissions at 80 percent below the 1990 levels requires extensive modification of the California energy sources and uses. This project developed a model that analyzes the many issues and controversial policy scenarios that would have to be addressed before the 2050 or interim GHG emission reduction targets can be met. The project developed a model called CA-TIMES. The model is a flexible bottom-up energy cost optimization model for California. Its flexibility lies in its ability to use technology specification and many other options by the modeler in a scenario format. To demonstrate the model, the contractor specified several scenarios. Two of the main scenarios reveal the need for significant investment in California's energy system, especially in the clean electricity production, because of major shifts in transportation and residential fuel use.

II. TECHNICAL SUMMARY

Objective

The objective of this project was to develop a model to better understand long-term energy, economics, and GHG emission reduction policy instruments and interactions for meeting long-term goals and targets at the lowest cost. The objective included the

ability to specify a business-as-usual (BAU) scenario and various scenarios for meeting targets beyond 2020 and investigate the costs, the policy bundles, and energy supply and demand mix.

Background

Assembly Bill (AB) 32 set a 2020 goal of reducing total California GHG emissions down to the 1990 levels. A Governor's Executive Order set a goal of reducing the emissions to 20 percent of 1990 levels, or an 80 percent reduction. The 2020 goal should be met once the already-adopted Climate Change programs and measures by ARB and other participating state and local agencies are fully implemented. The polices and the pathways that could lead to meeting the 2050 goal, or any potential interim milestones are still being debated both within and outside of ARB and require much needed quantitative analysis. As the programs for meeting the 2020 goal have shown, cost is a major criterion for decisions on selecting a path going forward. CA-TIMES, a model developed by this project, is such a tool capable of the needed quantitative analysis. CA-TIMES is based on an internationally developed set of algorithms for energy sectors and systems developed by the International Energy Agency and used in 37 countries. The algorithms are known as the MARKAL model, and can be made specific to a region by adding region-specific energy resources, demand, and technology data. The United States Environmental Protection Agency has developed such models for its nine regions.

The ARB adopted a Scoping Plan as required by AB 32 to meet the 2020 goal. AB 32 requires an update of the Plan every five years. The first update is scheduled for Board adoption in early 2014. The next one is scheduled for 2018. This project's CA-TIMES model can contribute significantly to the 2018 update. That update is likely to look beyond 2020, and set interim milestone on the way to meet the long-term 2050 target. The CA-TIMES can incorporate what was learned and achieved by the Plan into the baseline for long-term GHG emission reduction analysis of alternative pathways, and help inform the 2018 Scoping Plan Update.

Project Summary

In broad terms, the project consisted of the following tasks:

- Collecting California specific economic and energy data.

- Modifying the economic and energy modeling algorithms that process the interactions and constraints between economic sectors to search for a least cost set of technology, processes, and sector demand that meet a specified target, such as reducing GHGs by certain percentage.
- Building scenarios that represent AB 32 and other stated regulatory or policy objectives for beyond 2020.
- Running and analyzing the results of CA-TIMES model for several scenarios as demonstration of model capabilities.

The report covers analysis of several scenario model runs and sensitivity analyses of the scenarios. The scenarios can vary in four general categories, energy demand, technology, resource characteristics and costs, and policy specifications. The main, reference, or the BAU scenario (one scenario with three names in the report) includes the regulations, GHG reduction programs, and policies already on the books. There are two major GHG scenarios, one that includes the BAU and focuses on meeting 2050 GHG target in 2050 and beyond. This scenario is named GHG-Step. GHG-Step scenario maintains the 2020 cap through 2049, but reduces it to the 2050 target, hence the step name. The second GHG scenario reduces the cap linearly from 2020 down to the 2050 target. This scenario is called the GHG-Line. Neither one of these two scenarios impose any additional regulations or policies. Each one, however, are modified with policies into sensitivity scenarios. For example, the GHG-Step scenario was modified by imposing a faster growth rate for renewable electricity resources. This sensitivity scenario's name is GHG-S-HiRenGrowth.

The report analyzes the results of the two GHG emission scenarios of GHG-Step and GHG-Line, their corresponding sensitivity scenarios, and arrives at the following conclusions that,

- Without nuclear power and carbon capture and sequestration (CCS), reaching the 2050 target will be difficult.
- All of the scenarios reach a range of 270 to 340 $MMTCO_2e$ for 2035, including out-of-state marine and aviation emissions.
- Significant investment in wind and solar is needed for a timely ramping up of the capacity needed to meet the 2050 emission reduction target.

- As expected, electricity generation must be decarbonized tremendously if GHG targets are to be met.
- Light-duty vehicles powered by battery or fuel cells need to make up between 50 to 96 percent of the fleet in 2050.
- If CCS is available, biofuels can ameliorate constraints on other sectors.
- Decarbonized electricity will play major role in residential and commercial sectors' energy use, up to 75 percent.

The results of the CA-TIMES analysis were presented in refereed journals and conferences. The PI and the project team have contributed their time and effort beyond the contract's specifications. The results have been well received by the academic community.

III. STAFF COMMENTS

Staff in ARB's Research and Air Quality Planning and Science Divisions reviewed the draft final report (DFR). The version of the DFR previous to the one presented to the Research Screening Committee was extensively reviewed and scenarios were compared to the current status of the ARB Climate Change program polices. The contractor re-ran some of the scenarios incorporating ARB comments and revised parts of the report.

The project produced a model and demonstrated the model with scenarios specified to meet 2050 GHG target. The scenarios results are well presented with graphs and discussed adequately. Staff's comments are listed below.

1) Several editorial comments regarding report format, typos, title change, and sentence clarifications will be sent to the PI for further improvement of the report.
2) A few authors-comments to themselves are still in the report. The action stated in the comments need to be addressed and the comments removed.
3) The "SUMMARY FOR POLICYMAKERS" needs a clear listing of the scenarios and brief explanation to help the reader better understand the scope of the scenario analyses.
4) The SUMMARY needs to make it clear that the objective was to develop a model and demonstrate it with plausible scenarios.

5) All studies mentioned in the report need to be referenced properly.
6) Abbreviation list is incomplete.
7) All technical terminologies need to be fully defined before they are used (example, “hurdle rates”) or a glossary added to the appendices.

The ARB staff will be running the model in-house. The model consists of proprietary software and a set of Microsoft Excel worksheets and other computer codes. ARB has already procured the proprietary software. The University of California, Davis has been updating the model and the scenarios until recently. The components of the most recent version of the model that produced the results, as finalized in the final report, must still be transferred to the ARB staff.

IV. STAFF RECOMMENDATIONS

Staff recommends the Research Screening Committee accept this draft final report, subject to inclusion of appropriate additions and revisions in response to the staff comments and any changes and additions specified by the Committee.