STATE OF CALIFORNIA
AIR RESOURCES BOARD

MEETING OF THE

RESEARCH SCREENING COMMITTEE

January 30, 2015
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 30, 2015
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 3, 2014
9:00 a.m.

MINUTES

RSC Members in Attendance via teleconference

Harold Cota
Forman Williams
Steven Japar
Suzanne Paulson
Rachel Morello-Frosh
Alan Vette
Rashid Shaikh
Yifang Zhu
William Eisenstein

The Research Screening Committee (RSC or Committee) convened the meeting at 9:05 a.m. The minutes of the July 17, 2014 meeting were approved.

I. New Research Projects

1) "Collection of Tractor-Trailer Activity Data," University of California, Riverside, $500,000, Proposal No. 2782-281

A Committee member noted that the project has been revised to focus on activity data collection, including surveys and data loggers. The member commented that the data loggers are a component of the project that incurs a significant cost, and asked what information the data loggers would add to the information collected by the surveys. Staff from the California Air Resources Board's (ARB) Mobile Source Control Division responded that the data loggers are considered to be an important element of the project because of the vehicle speed profile data they will collect. Staff noted that the effectiveness of aerodynamic improvement components is highly dependent on vehicles traveling at higher speeds, and the data loggers would permit actual speed data to be collected from different tractor-trailers to determine the vehicle speed profiles, and to assess the potential effectiveness of aerodynamic improvement components based on these speed profiles.

Motion: Move to accept the proposal, subject to inclusion of revisions based on comments from staff and the Committee.

The Committee approved the proposal. Rashid Shaikh abstained from voting.

II. Draft Final Reports

1) "Evaluation of Pollutant Emissions from Portable Air Cleaners," Lawrence Berkeley National Laboratory, $400,000, Contract No. 10-320

Committee members who submitted written comments for the draft final report were asked if they were satisfied with staff's written responses to their comments. They stated that staff responses were satisfactory.

One Committee member asked why the blue bars of the graphs on page 67 show elevated levels for formaldehyde when the device was turned off. Staff responded that the tested device was a dual function device, having both a heater and an ionizer, and that the measured formaldehyde levels were due to background levels. Staff further clarified that low levels of formaldehyde are prevalent in ambient air and that its levels are never zero, and that the test chamber did have minor leakage points which allowed some unfiltered air (containing formaldehyde) to enter.

Motion: Move to accept the report, subject to inclusion of revisions based on comments from staff and the Committee.

The Committee approved the report.

2) "On-Road Measurement of Emissions from Heavy-Duty Diesel Trucks; Impacts of Fleet Turnover and ARB's Truck and Bus Rule," University of California, Berkeley, $300,012, Contract No. 09-340

The Committee in general praised the report as well written. Some issues were raised that need to be addressed in the revised final report:

- Change the units of Y-axis for Figures 16a and 16b to dN/dlogDp and for Figures 17a and 17b to dM/dlogDp if appropriate
- Add text explaining why the OEM DPF mass distribution in Figure 17a peaks
- Explain why the peak for OEM DPF is at 500 nm in figure 17a while for other
- Describe whether or not the investigators were able to determine if trucks were regenerating at the time of plume capture, which could give elevated emissions and incorrectly indicate a malfunctioning DPF;
- Provide the ratio of successful plume capture vs. total plumes for 2011 and for 2013.

The Committee also recommended that better statistical analysis including factor analysis be incorporated in future work as well as quantification of effects on ambient air quality.

Motion: Move to accept the report, subject to inclusion of revisions based on comments from staff and the Committee.

The Committee approved the report.

3) "Cool California Carbon Challenge: A Pilot Intra-Inter-Community Carbon Footprint Reduction Competition," University of California, Berkeley, $300,004, Contract No. 10-325

One Committee member requested that the researchers add a section on costs to run the program, asked that the report clarify that "n" refers to survey sample size on page 15, requested that the language on pages 18 and 81 (explaining that surveys were voluntary and why) be made consistent, and asked that the researchers clarify that the data shown on pages 52-53 was collected during this research project. Another Committee member requested that the researchers elaborate on some of their findings: that the City of Tracy, and residents in all of the participating cities who were skeptical of human-induced global warming, were not the "usual" participants in this type of program and yet they performed well in the competition; this competition led to a 14 percent reduction in electricity use, and the Committee member asked that the report consider whether this may be an upper bound on the achievable savings that would result from a competition like this one. The Committee member also asked for more explanation of the "alternate calculation methodology," referenced on page 45, for determining the amount of CO_2 emissions reduced through the competition. And finally, this Committee member suggested that the researchers consider slightly different methods for future surveys to overcome some of the limitations of the survey results in this study.

Motion: Move to accept the report, subject to inclusion of revisions based on comments from staff and the Committee.

The Committee approved the report.

4) "Quantifying the Comprehensive Greenhouse Gas Co-Benefits of Green Buildings," University of California, Berkeley, $180,000, Contract No. 11-323

The Committee commented that Table 1 needs to be corrected as the definition of measured value and predicted value were switched. They also requested that more explanation be given to clarify the transportation methodologies, and in particular, to explain the significant limitations encountered as a result of limited data provided through the Leadership in Energy and Environmental Design for Existing Buildings: Operations and Maintenance (LEED-EBOM) certification process, including that the Average Vehicle Ridership data does not provide insight into what strategies, if any, the individual buildings may have used

(telework, commuter benefits, etc.). Given the size of the transportation impacts of buildings, this additional clarity is particularly important. Additionally, the Committee noted that the recommendations made to improve data on transportation impacts of buildings were appropriate and suggested including in the Recommendations Section that the American Community Survey collect information on individual people's workplace building type, despite likelihood.

The Committee recommended packaging the results in the tables on pages 23-28 in a visual format (e.g. pie charts) to make it easier to visualize/digest the information. It was also suggested that these graphs be included in the Discussion Section so that the reader doesn't have to frequently refer back to the Results. The Committee also asked that Figure 4 on page 32 note what each horizontal line represents.

Motion: Move to accept the report, subject to inclusion of revisions based on comments from staff and the Committee.

The Committee approved the report. William Eisenstein recused himself from the discussion of this item.

III. Other Business

1) Update on the 2015-2016 Annual Research Plan

Staff provided the Committee with an update on the 2015-2016 Research Plan process. The current status of the Plan is that staff has a list of proposed projects that will be included in the Plan, and will soon develop more detailed scopes of work for those projects which will form the basis for a solicitation for proposals that will be released in mid-December. The Plan will also be presented to ARB's Board in mid-December. Proposals in response to the solicitation will be due in early February, 2015 and accepted proposals will be shared with the Committee in May, 2015.

Several Committee members provided comments on the proposed projects. One Committee member commented that the proposed projects were not duplicative and represented a good body of work. Another Committee member commented on the project on "tracking land use" that it was a good idea and worth doing, but that the description focused on land use designations, which may diverge from what actually gets developed, and noted that it was worthwhile to ensure that general plans are consistent with Sustainable Communities Strategies objectives. The Committee member also commented that the "zero carbon building" project was ambitious at this point, and that this seemed like more of a long-range strategy relative to the other proposed projects. One Committee member commented that it was nice to have summaries of ongoing research. Two Committee members requested additional time to provide comments on the projects.

The meeting adjourned at 10:05 a.m.

DISCUSSION OF A PROPOSED CONTRACT AUGMENTATION
ITEM NO.: II.1
DATE: January 30, 2015
CONTRACT NO.: 11-322

STAFF EVALUATION OF A PROPOSED CONTRACT AUGMENTATION

TITLE:	Modeling Household Vehicle and Transportation Choice and Usage
CONTRACTOR:	University of California, Davis
PRINCIPAL INVESTIGATORS:	David S. Rapson, Ph.D. Patricia Mokhtarian, Ph.D.
CONTRACT TYPE:	Interagency Agreement
TOTAL AMOUNT:	$45,000
CONTRACT TERM:	48 months

For further information, please contact Dr. Annalisa Schilla at (916) 322-8514.

I. SUMMARY

A contract augmentation is requested to cover unanticipated expenses and delays associated with changes in the Air Resources Board's (ARB) policy for handling confidential Department of Motor Vehicles (DMV) data for research purposes. This dataset is fundamental to the development of the vehicle choice and usage model which this contract will deliver. The two tasks in this contract will support ARB efforts to reduce greenhouse gas and criteria pollutant emissions from the transportation sector. The first major component of the project focuses on understanding the factors that lead some Californians to a small transportation emissions footprint. It will identify the geographic and demographic characteristics of these low transportation emissions households. This first component of the project is on track and is not affected by this proposed augmentation. The second major component of the proposed project focuses on jointly modeling the consumer decision process about when to buy a vehicle, what type of vehicle to buy, and how much to drive the vehicle. This will allow for a more rigorous evaluation of the effects of policies that influence either the choice of vehicle or the usage of vehicles and will shed light on consumer valuation of different vehicle

attributes. The results will provide valuable insights in support of ARB's Sustainable Communities and Advanced Clean Cars programs, and will provide a more sophisticated understanding of the evolution and emissions of the light-duty fleet.

II. TECHNICAL SUMMARY

Objective

This augmentation will allow Co-Principal Investigator (PI) David Rapson to complete the development of the vehicle choice and usage model and to run the counterfactual scenarios which will provide deeper insight into the linked consumer decisions of what car to buy and how much to drive it. This model will be a valuable tool to inform future policies that aim to reduce emissions from the light-duty fleet.

Background

This project was approved by the Research Screening Committee in 2012 to advance ARB's research related to forecasting new vehicle purchases, and to provide insight into the factors that enable some households to voluntarily maintain low emission transportation footprints (i.e., low or zero vehicle miles traveled [VMT] or vehicle ownership). The primary task for Co-PI David Rapson is to develop, test, and run a vehicle choice and usage model that is more sophisticated than previous models and accounts for drivers' anticipated usage of the vehicle in their purchase decision, as well as a more comprehensive set of market factors (i.e., beyond just fuel prices). The development of this model relies on a variety of datasets, the most important of which is the DMV data.

Between the time that this contract was approved by ARB's Board in April, 2012, and the kickoff meeting in October, 2012, ARB's policy on sharing confidential DMV data with contractors changed. The original work plan for this contract anticipated that ARB would provide the DMV dataset directly to the contractors, but the new policy no longer allowed this. In order to provide the DMV data to the contractors, ARB and the contractors developed a complex process of anonymizing the DMV data while also preserving personal and household identifiers. Although ARB staff are creating the anonymous personal and household identifiers that will ultimately be shared with UC Davis, David Rapson, Kenneth Gillingham, and graduate student Stephen Sun have

been spending considerable additional unanticipated time working with ARB staff to develop the process and methodology for creating the household-level DMV dataset to ensure that important records are retained and to ensure that the dataset is as useful as possible for the model that will be constructed. A number of redundant steps have been added to the project to allow the research team to begin the model design while they await the delivery of the anonymized DMV data, and these steps will need to be repeated and/or completed once the DMV data is provided by ARB. The resulting process has been significantly more complicated and has required much more time from highly-paid personnel (Co-PI David Rapson and Subcontractor Kenneth Gillingham) than was originally anticipated (for example, meetings and phone calls to develop the protocol for household and personal ID generation, troubleshooting and other support). As a result, the work plan requires substantial revisions and an augmentation of $45,000 to ensure that personnel support is adequate to complete all of the key tasks that were outlined in the original contract.

Proposal Summary

The proposed augmentation will allow the research team to complete the design, coding, and testing of the vehicle choice and usage model, run the counterfactual simulations, and develop forecasts of the future vehicle fleet. This model of household vehicle choice and usage will examine the relationships among: VMT, gasoline price, and fuel economy; household income and response to gasoline price and fuel economy; population density and other locational characteristics and gasoline price/fuel economy; and will explore the diffusion of low-emissions vehicles, including where they are and attributes of households holding them. The team will then determine vehicle classifications for choice mode and scenarios for counterfactuals/projections (both in collaboration with ARB), determine the framework for (and then code) the structural model, and ultimately run the model on a subsample of the data and then on the full dataset. Finally, the research team will perform suitable robustness checks, calculate summary statistics (elasticities, survival curves), and calculate vehicle fleet projections under counterfactual scenarios.

III. STAFF COMMENTS

The Co-PI, David Rapson, has worked diligently to maintain progress toward the development of the vehicle choice and usage model in spite of the lack of the anonymized DMV dataset. The augmentation will restore funds diverted to additional and more complex steps to develop an anonymized DMV dataset that retains personal and household identifiers and will allow the research team to complete development of the model, run the counterfactual simulations, and develop forecasts of the future vehicle fleet.

IV. STAFF RECOMMENDATION

Staff recommends the Research Screening Committee approve this proposed augmentation for a total amount not to exceed $45,000, subject to inclusion of any changes and additions specified by the Committee.

DISCUSSION OF A DRAFT FINAL REPORT
ITEM NO.: III.1
DATE: January 30, 2015
CONTRACT NO.: 09-330
Link to Report

STAFF EVALUATION OF A DRAFT FINAL REPORT

TITLE:	Health Effects of Central Valley Particulate Matter
CONTRACTOR:	University of California, Davis
PRINCIPAL INVESTIGATOR:	Anthony Wexler, Ph.D.
CONTRACT TYPE:	Interagency Agreement
TOTAL AMOUNT:	$496,429
CONTRACT TERM:	36 months

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

I. SUMMARY

Epidemiological studies have demonstrated that health effects associated with particulate matter (PM) are often not apparent until one to three days after exposure. However, the temporal patterns for development of pulmonary and cardiovascular responses appear to differ. Little is understood as to whether adverse changes in respiratory and cardiovascular endpoints represent independent effects that have different time courses for development, or whether they represent a continuum of effects that share common biological pathways and are inter-related. In addition, past studies have evaluated all endpoints at the same time post-exposure. Because of this, little is known about the time course for development of respiratory and cardiovascular effects. This project investigated how time lags in exposure increase or diminish pulmonary and cardiovascular responses in a mouse model that has similar pulmonary and systemic responses to PM as humans. The study also investigated the effect of two different methods of removing particles from collection filters on particle composition and elicitation of biological effects. The hypothesis of this project was that local pulmonary inflammatory responses in the airways of the lung precede, and then initiate

vascular inflammation and subsequent platelet activation. The results demonstrate that responses of different endpoints do not have the same temporal patterns, explaining some of the lack of concordance between published studies. In addition, the method used to remove particles from the monitoring filter influences particle composition and toxicity. These findings provide new information on the biological mechanisms through which PM adversely impacts health. Moreover, the temporal patterns observed in different endpoints, as well as the findings from the particle extraction analysis, will influence experimental designs for future studies so that they are optimal to capture time varying effects.

II. TECHNICAL SUMMARY

Objective

The objective of the proposed work was to investigate the toxicity and inflammatory potential of urban and rural Central Valley PM on pulmonary, vascular and systemic health effects in a mouse model through the examination of health-related endpoints at one, two and four days following a single aspiration exposure to ambient particles collected in either in downtown Sacramento or at a rural site on the campus of the University of California, Davis.

Background

Numerous epidemiologic studies demonstrate that elevated levels of PM10 and PM2.5 are associated with increased acute morbidity and mortality. Results from the Southern California Children's Health Study have shown that children growing up areas with higher levels of air pollution have lower lung function, which may predispose these children to acute and prolonged adverse respiratory health effects once they attain adulthood. In addition, epidemiological studies have also shown that respiratory and cardiovascular health effects are most associated with ambient PM concentrations one to three days previous to the advent of the adverse health response (lags 1 to 3), although respiratory and cardiovascular effects seem to have different lag structures. To date experimental human and animal studies have measured all respiratory and cardiovascular endpoints at the same time, even though the epidemiologic literature suggests that the greatest effects on the various endpoints examined to date do not peak at the same time. Consequently, it is possible that important information on the

temporal pattern of respiratory and cardiovascular responses and their interrelationships has been missed.

Proposal Summary

The study involved three parts: (1) selection of particle preparation method, (2) selection of the dose of particles to be used, and (3) investigation of the lag structure of the various endpoints. First, the investigators used two methods to remove particles from pieces of the same PM2.5 collection filter. Briefly, one method was sonication in ultrapure water, and the other involved multiple solvents. The resulting particles were extensively characterized, and were also used in some cellular assays to investigate differential toxicity. The second step was a dose-response animal exposure study to compare biological responses to particles removed from monitoring filters by the two methods, and to select the exposure dose for the lag structure study. Although the multi-solvent method removed a larger fraction of particles from the filter, the particles proved to be less potent in inducing inflammatory responses, and the dose response relationship was not as clear as that of the water-extracted particles. As a result, the investigators elected to use the water-extracted particles for the third arm of the study, which focused on investigating the lag structure of different biological endpoints.

BALBc mice were exposed to PM2.5 via intra-tracheal aspiration. Control animals aspirated a sham solution. All animals in a group were exposed at the same time, with sub-sets sacrificed at one, two and four days post-exposure. Endpoints included lung inflammatory mediators, endothelial and platelet function, studies of lung histopathology and anti-oxidant gene expression using standard methods. In addition, analyses were conducted for lung and systemic markers of inflammation, inflammatory cell differential in the lungs, histology and gene expression of anti-oxidant genes in the lung tissue, while complete blood count, platelet activation and function studies were used to assess systemic procoagulant responses.

The study had two key findings. First, the method of extraction of PM from the filter or impactor substrate has a significant effect on the health effects elicited. Second, as expected, some of the endpoints, especially the pulmonary ones, showed peak responses to the PM at one or two days post-exposure, while other endpoints,

especially systemic ones, appeared later, with larger delays in initiation, in agreement with epidemiological studies on cardiovascular responses to PM.

III. STAFF COMMENTS

The investigator submitted one previous draft of the report that was reviewed by two ARB staff. The present version incorporates responses to the comments from the previous review, and was reviewed by four ARB staff and a scientist from United States Environmental Protection Agency (U.S. EPA). Overall, the reviewers found the report to be well written and interesting. There are several typos and minor editorial issues that should be corrected in the final version of the report. Several points were noted where provision of more detail would aid clarity.

The results help to explain inconsistencies in the body of literature on the health effects of PM exposure. In addition, the results provide important guidance for sample collection, endpoint assessment timing, and particle extraction methodology in future studies.

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.: III.2
DATE: January 30, 2015
CONTRACT NO.: 10-319
Link to Report

STAFF EVALUATION OF A DRAFT FINAL REPORT

TITLE:	Risk of Pediatric Asthma Morbidity from Multi-Pollutant Exposures
CONTRACTOR:	University of California, Irvine
PRINCIPAL INVESTIGATOR:	Ralph J. Delfino, MD, Ph.D.
CONTRACT TYPE:	Interagency Agreement
TOTAL AMOUNT:	$285,000
CONTRACT TERM:	24 months

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

I. SUMMARY

One of Air Resources Board's goals is the protection of sensitive populations, such as children, from air pollution impacts. Numerous studies have shown a link between particulate matter (PM) exposure and asthma morbidity outcomes in children; however, several issues regarding the biologically active components of PM remain to be addressed. There is limited information on the impact of primary organic aerosols (POA) directly emitted from combustion sources, and secondary organic aerosols (SOA) which are largely photochemically-produced, on the risk of acute asthma morbidity among children. This study analyzed the possible relationship between asthma morbidity (using hospital data for 7,954 children with asthma) and both regional and local exposures to PM including POA and SOA in Orange County. The UC Davis/California Institute of Technology (UCD/CIT) Source Oriented Chemical Transport Model was used to output daily POA and SOA concentrations. Traffic-related air pollution (TRAP) was assessed using CALINE4 dispersion models at subject residential locations for ultrafine particle number concentrations as well as PM2.5, and NO_X concentrations averaged seasonally and weekly. Acute asthma morbidity was found to be increased in relation to short-term elevations in various indicators of air

pollution (CO, NO_2, NO_X, TRAP, and POA from on-road and off-road diesel plus gasoline emission sources). There were no associations with SOA in either season. Associations of asthma with ambient CO, NO_2, NO_X, and PM2.5, were stronger among subjects living in homes near high TRAP suggesting that this is a vulnerable population. Assessing the important sources and components of PM2.5 that are related to health outcomes could aid ARB by targeting specific PM2.5 sources for future control measures.

II. TECHNICAL SUMMARY

Objective

The main objective of the study was to determine the relationship between exposure to POA and SOA and asthma morbidity in children. This was studied using PM predictions (size-resolved mass, speciation and source apportionment) generated by regional air quality models. The study also evaluated whether temporal and spatial variations of PM2.5 species affect the association between PM2.5 mass concentrations and emergency department visits and hospital admissions for asthma. Finally, air pollution susceptibility, including asthma recurrence, socioeconomic status, insurance status and demographic factors were evaluated.

Background

Asthma morbidity, including hospital admissions, has been shown to be associated with daily concentrations of ambient air pollution in many studies. However, there is a lack of data on the health effects of traffic-related air pollutants estimated at a fine spatial resolution (500m) versus regional exposure to O_3 and PM2.5. Also, little is known about the health effects of POA and SOA. These particle types have different spatial and temporal variability. POA is the predominant mass fraction in near-roadway ultrafine particles and SOA comprises a large part of accumulation mode particles (0.1-2.5 µm). POA components are more hydrophobic, and SOA components are more hydrophilic. These characteristics may affect their relative toxicities and differential effects in human airways. Many studies support a role for POA from fossil fuel combustion (e.g. polycyclic aromatic hydrocarbons) in increased airway inflammation through oxidative stress mechanisms. However, there is insufficient epidemiologic data to clarify the roles of POA vs. SOA in associations with asthma morbidity. This study was designed to address these research gaps.

Project Summary

The study used PM predictions generated by regional air quality models to study the relation of asthma morbidity in 7,954 children ages 0-18 years to daily exposure to POA and SOA. The subjects in the study acted as their own control. The period of exposure was the week leading up to the day each subject was seen at hospital, and this was compared to a referent exposure period from the same days of the week and month. The hospital data included 11,390 hospital encounters (emergency department visits and hospital admissions) from 2000-2008 for a primary diagnosis of asthma in Orange County. The UCD/CIT Model was used to output daily POA and SOA at a 4x4 km resolution for the subject residences. POA and SOA model output included size-resolved mass, speciation, and source apportionment. Ambient air pollutant and weather data were obtained from United States Environmental Protection Agency AIRS. TRAP was assessed using CALINE4 dispersion models at subject residential locations for ultrafine particle number concentration, PM2.5, and NO_x averaged seasonally (warm season: May-October; cool season: November-April) and weekly.

Model prediction of the UCD/CIT model showed wood smoke was the single biggest source of POA in winter, and meat cooking and other anthropogenic sources (including solvent use) and mobile source emissions are the most important sources in summer. Predicted SOA concentrations were generally low, with biogenic emissions being the largest SOA source, followed by the other anthropogenic (including solvent use) and mobile sources.

In health outcome analyses, hospital encounters (emergency department visits and admissions) for asthma were positively associated with ambient air pollution data, including PM2.5 and O_3 in the warm season and PM2.5, CO, NO_2, and NO_x in the cool season. Associations of daily ambient air pollution with asthma hospital morbidity were stronger among subjects living at residences with higher CALINE4 predicted air pollution from traffic, especially in the cool season. Residential TRAP exposures were significantly associated with asthma hospital encounters in the cool season. No associations were found in the warm season with SOA and POA, but positive

associations of POA (including most specific sources) were found with asthma in the cool season.

Results of the multi-pollutant models suggest that effects of warm-season ambient O_3 and PM2.5 are largely independent of each other and not confounded by any other air pollutant. Cool season PM2.5 was also not confounded by any other air pollutant. Associations between asthma outcomes and ambient PM2.5, NO_2, and CO in the cool season were stronger among Hispanics compared with non-Hispanic whites. Hispanic and African American subjects as well as subjects without private insurance tended to live in residences associated with higher levels of traffic-related air pollution which further increases the vulnerability of these populations. Older children (≥12 years) and female children showed a tendency for increased sensitivity to several air pollutants, particularly PM2.5 and NO_2. Asthma outcomes were more strongly associated with PM2.5 exposures in subjects living in lower socioeconomic neighborhoods.

III. STAFF COMMENTS

Eight staff in the Research Division with different areas of expertise reviewed and commented on the draft final report. The comments were sent to the investigator. A revised version of the report addressing all the requested comments was submitted to the Research Screening Committee for review and comment.

The research findings from this project support the growing literature that certain populations, including different ethnic and socioeconomic groups, are more vulnerable to the effects of high exposures to traffic-related air pollution near residential locations. This study emphasizes the importance of reducing sources of traffic emissions.

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.: III.3
DATE: January 30, 2015
CONTRACT NO.: 11-310
Link to Report

STAFF EVALUATION OF A DRAFT FINAL REPORT

TITLE:	Reducing Air Pollution Exposure in Passenger Vehicles and School Buses
CONTRACTOR:	University of California, Los Angeles
PRINCIPAL INVESTIGATOR:	Yifang Zhu, Ph.D.
CONTRACT TYPE:	Interagency Agreement
TOTAL AMOUNT:	$150,000
CONTRACT TERM:	42 months

For further information, please contact Peggy Jenkins at (916) 323-1504.

I. SUMMARY

For most Californians, the highest personal exposure to particulate matter (PM) occurs while commuting on roadways. The investigators assessed the effectiveness of utilizing high efficiency cabin air (HECA) filters in cars and high efficiency filtration systems in school buses to mitigate commuter roadway PM exposures. Ultrafine particles (UFP), black carbon (BC) and PM2.5 were concurrently monitored inside and outside of each vehicle under three driving conditions: stationary, on local roadways, and on freeways. The effectiveness of two types of HECA filters relative to the original equipment manufacturer-supplied (OEM) filter was evaluated in 12 cars, which were operated with the vents open to prevent CO_2 build-up from occupants' exhaled breath. The effectiveness of the bus HECA system was evaluated by measuring in-cabin particle levels in 6 school buses with and without the HECA filtration system operating. When cars were outfitted with HECA filters, average in-cabin reductions of 89 percent (UFP), 82 percent (BC), and 64 percent (PM2.5) were achieved, relative to the measured on-road ambient concentrations. These reductions were about twice the reductions achieved with the low efficiency manufacturer-supplied filters, which showed reductions of 29 percent to 46 percent. When the bus HECA filtration system was operating,

average reductions of 89 percent (UFP), 85 percent (BC), and 73 percent (PM2.5) were achieved inside the bus, relative to the measured on-road ambient concentrations. High efficiency filtration appears to be a potential mitigation strategy available in the near-term to reduce vehicle occupants' exposure to roadway PM and provide additional health protection while ARB's emission control measures are implemented and fleet turnover occurs over time.

II. TECHNICAL SUMMARY

Objective

The general objective of this study was to explore the application of high efficiency filtration to reduce exposure to UFP, BC and PM2.5 in passenger cabins. The specific objectives were to:

1. Determine the extent to which HECA filters can reduce fine and ultrafine particle levels inside the passenger cabin of vehicles.
2. Identify important factors affecting the performance of HECA filters in passenger vehicles.
3. Determine the extent to which installing a HECA system can reduce fine and ultrafine particle levels inside of school buses.
4. Identify important factors affecting the performance of HECA systems inside school buses.

Background

Research has shown that exposure to traffic-emitted particulate matter can be associated with adverse health effects such as asthma, cardiovascular disease and even premature death. And while this exposure is significant and has been linked to important health concerns, few studies have investigated specific methods to reduce in-cabin particle exposures of commuters.

Low efficiency cabin air filters are generally standard equipment in newer automobiles to remove larger particles (e.g. pollen) from the outside air and re-circulated air as it enters the cabin of the vehicle. In studies testing the effectiveness of passenger cabin supplied air filters, a large range of filtration efficiency was observed. The large variation among filters suggests that a higher efficiency cabin filter may dramatically reduce the

penetration of fine and ultrafine particles into the cabin. The few earlier reports on the use of high efficiency filters in automobiles achieved dramatic reductions when the in-cabin air was re-circulated and no outside air was brought into the cabin. However, some investigators noted that high carbon dioxide (CO_2) levels occurred under such conditions due to exhaled occupant breath - levels that exceeded indoor air guidelines and the CalOSHA PEL for CO_2. One recent study has shown that such levels of CO_2 can impair human decision-making performance, which is especially important for safe driving.

In contrast to passenger vehicles, school buses are usually not equipped with replaceable cabin filters. This is especially true for older buses with no built-in air conditioning or mechanical ventilation systems. In newer buses with air conditioning systems, a low efficiency filter (i.e. <MERV 5) is usually installed to remove larger particles before the air reaches the blower fan and the evaporator. This filter could be replaced by a high efficiency filter to reduce roadway particles in the cabin of school buses. Alternatively, the cabin air could be filtered while being circulated through a built-in ventilation system capable of re-circulation, if available on the bus, or through a high efficiency air filtration system placed in the cabin. All of these approaches would enable high efficiency filtration to be tested as a mitigation approach that could be incorporated into bus ventilation design in the future.

Project Summary

Two types of HECA filters (i.e. HECA A and HECA B) were used that were developed with an industry partner to incorporate filtration media composed of nano-fibers that are much smaller in diameter than typical fibers used by common OEM filters. The HECA A was designed to have improved particle removal efficiency while maintaining a limited pressure drop. The HECA B filter was designed to maximize particle removal efficiency. Each HECA filter was custom made to replace each OEM filter installed in the car's cabin air filter housing. For buses, a prototype on-board HECA system was developed with an industry partner, and utilized HECA B filters.

Twelve cars (model year range 2010-2013) of varying sizes, makes, and models were tested. Testing was conducted with the vents open (i.e. the recirculation mode turned

off) to prevent CO_2 build-up. Six school buses (model year range 2006 to 2013) of different capacities, fuel type, and makes were selected for testing. All diesel-fueled buses were equipped with a diesel particulate exhaust filter. All field measurements were made under three driving conditions (i.e., stationary, on local roadway, and on freeway) on roadways located in Los Angeles, California.

The removal performance of HECA filters in cars was tested under four different filtration scenarios, i.e., with no filter and with in-use OEM, HECA A, and HECA B filters. The HECA bus filtration system was tested under two scenarios, while turned off and turned on in school buses. In-cabin and on-roadway pollutant levels, including CO_2, were concurrently monitored by two sets of condensation particle counters, DustTraks, aethalometers, Q-traks, and, in larger vehicles, scanning mobility particle sizers.

Cars outfitted with HECA filters were found to have average reductions of 89 percent (SD 8), 82 percent (SD 12), and 64 percent (SD 28) under all driving conditions, for in-cabin UFP, BC, and PM2.5, respectively, relative to the measured on-road ambient concentrations. Throughout field testing of the 12 passenger vehicles, the in-cabin CO_2 concentration remained in the range of 620 to 930 ppm, significantly lower than the typical levels of 2,500 to 4,000 ppm observed when vents are closed in the re-circulation mode. Cars outfitted with OEM filters were found to have average reductions across all driving conditions of 46 percent (SD 18), 31 percent (SD 17), and 29 percent (SD 20) for in-cabin UFP, BC, and PM2.5, respectively, relative to the measured on-road ambient concentrations. When the bus HECA filtration system was operating, average reductions across all driving conditions of 89 percent (SD 7), 85 percent (SD 6), and 73 percent (SD 20) were achieved for in-cabin UFP, BC, and PM2.5, respectively, relative to the measured on-road ambient concentrations. With the HECA system off, in-cabin bus levels for the particulate pollutants were lower than the measured on-road levels under stationary conditions, but in-cabin UFP (for some buses), BC and PM2.5 levels were higher than on-road levels under local roadway and freeway conditions. The investigators suggested that this may be due to bus self-pollution.

Overall, the particle reductions achieved in cars using high efficiency filters were about twice the reductions achieved with the low efficiency manufacturer-supplied filter. In-cabin exposure reduction in all tested vehicles was greatest for UFP, followed closely by BC, and was somewhat less for PM2.5. This is likely due to the different size ranges of the measured particles and the different particle behavior/removal mechanism for each size range.

III. STAFF COMMENTS

A preliminary draft final report was provided for review and comment to staff of ARB's Research, Mobile Source Control, and Emissions Compliance, Automotive Regulations and Science Divisions. A subsequent version of the report was submitted and addressed staff's main comments. The field work conducted and the content of the report meet the contract requirements.

This study suggests that high efficiency filtration appears to be a potential mitigation strategy available in the near-term to reduce vehicle occupants' exposure to roadway PM and to provide additional health protection while ARB's emission control measures are implemented and fleet turnover occurs over time. This study also provides a "proof-of-concept" for reducing in-cabin particulate levels in school buses via a prototype HECA filtration system. Completion of this work is important because an increasing number of studies have documented the much greater occurrence of serious health impacts ─ such as increased asthma and respiratory disease, increased heart disease, reduced birth weight, decreased lung function, and various immune system effects ─ experienced by those living near busy roadways and spending time on roadways. Significant effects have especially been seen in children. Additional data are needed to assess the performance of in-vehicle high efficiency filtration under long-term use conditions with vents open, and to examine any potential impacts on fuel usage, ventilation system performance, maintenance needs, and costs.

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.: III.4
DATE: January 30, 2015
CONTRACT NO.: 10-311
Link to Report

STAFF EVALUATION OF A DRAFT FINAL REPORT

TITLE:	Development of a Portable In-Use Reference Particulate Matter Measurement System
CONTRACTOR:	University of California, Riverside
PRINCIPAL INVESTIGATORS:	Kent Johnson, Ph.D. Tom Durbin, Ph.D.
CONTRACT TYPE:	Interagency Agreement
TOTAL AMOUNT:	$300,000
CONTRACT TERM:	48 months

For further information, please contact Dr. John Collins at (916) 327-8097.

I. SUMMARY

Heavy-duty diesel trucks are an important source of particulate matter (PM) emissions in California. The Statewide Truck and Bus Regulation implemented in 2007 have accelerated the use new technology engines. For PM emissions, this rule has already resulted in retrofit or replacement of nearly the entire on-road fleet with engines equipped with diesel particulate filters (DPF) to reduce PM emissions. There is a need for accurate measurement of in-use PM emissions using Portable Emissions Measurement Systems (PEMS) to evaluate in-use compliance, to improve the emission inventory, and to evaluate commonly used real-time PM instruments against gravimetric reference methods. Unlike PEMS systems for measurement of nitrogen oxides (NO_X), the reliability of commercially available PEMS using real-time PM instrumentation is questionable at the low PM emission levels of DPF equipped vehicles. The results of light scattering and absorption methods used by commercially available real-time PM instrumentation are highly dependent on particle size, composition, and concentration, and can result in large deviations from reference gravimetric methods.

The goal of this project was to develop a new filter-based PM PEMS to measure in-use PM emissions using a gravimetric method with focus on equivalence to the federal reference methods. The gravimetric PM PEMS should be adaptable to characterize PM emissions from diverse activities including on-highway, non-road, and marine applications. The instrument was designed based on the measurement principles specified in 40 Code of Federal Regulations (CFR) 1065 for gravimetric mass measurements using proportional sampling. The design included an automatic filter switching system that can collect multiple filter samples during a single test drive, in order to cover various driving modes, not-to-exceed (NTE) events, and sampling windows fixed time, total mass, and other approaches of interest to ARB.

The design was implemented and tested in an iterative process. The final design was arrived at by looking at best practices for each component. The components chosen include a remote diluter manufactured by AVL, a proportionality methodology by Sensors, a filter flow variable pump controller by Control Systems, and multi-filter auto indexing system by AEI. The investigators utilized the component from each vendor and created a cohesive sampler that is simple to operate, has low power requirements, and is light weight. The final version of the system demonstrated good equivalence with gravimetric PM emission measurements made using a full scale, 40 CFR 1065 compliant, Constant Volume Sampler (CVS) system.

II. TECHNICAL SUMMARY

Objective

The major objective of this research was to identify the best practices from industry for gravimetric measurement PM emissions from heavy duty vehicles, and to implement these practices in a portable in-use gravimetric PM PEMS. A unique goal for the system is the ability to sample on up to 30 filters in a given test day, which allows enough flexibility for the system to be deployed for normal in-use operation, using a controller to identify sample windows and an automatic indexer to switch from filter to filter. The PM system was designed to meet 40 CFR 1065, 1066, and International Organization for Standardization (ISO) 16183 reference methods, and to do so during in-use testing.

Background

Regulations adopted under the ARB's Diesel Risk Reduction Plan have led manufacturers to adopt new control technologies which have caused significant changes in the magnitude, formation, and composition of diesel exhaust PM. This tool will assist ARB to quantify PM emissions from new technology vehicles outside of the laboratory under real-world, in-use operating conditions. This information will allow ARB to evaluate the real-world performance of the new technologies, and to improve our mobile source PM emission inventories.

Project Summary

The gravimetric PM PEMS system was designed, constructed and then tested for functionality, proportionality, and overall system accuracy on a chassis dynamometer as well as during in-use emissions sampling. This involved an iterative process to arrive at the system that met the requirements of 40CFR1065. Four different versions were evaluated as listed below on a chassis dynamometer (Version 1.0, 1.1, 2.0a and 2b) and during in-use testing (Version 2a) at differing environmental conditions. Version 2b is the final system being provided to the ARB by the investigators.

Version 1.0 and 1.1

Version 1.0 of the gravimetric system utilized two TSI flow meters to measure sample flow and total flow for dilution calculations with bypass control system designed to maintain constant flow. System was found unstable related to exhaust flow changes and was upgraded to Version 1.1 utilizing mass flow controller and TSI flow meters. Both Versions 1.0 and 1.1 were tested on a chassis dynamometer without an indexer and therefore represent the ability to sample proportionally and to quantify mass at 40CFR1065 conditions. The sampling utilized a heavy-duty diesel vehicle equipped with a continuously regenerating technology (CRT) DPF. The brake-specific PM emissions in the tailpipe exhaust were varied using a bypass system in which a portion of the exhaust flow was split into two streams, one passing through the DPF, and one bypassing the DPF, and then recombined allowing the investigator to control the level of PM emissions in the exhaust. The chassis dynamometer testing was done on the Urban Dynamometer Driving Schedule (UDDS) cycle at 20 percent DPF bypass (PM dominated by elemental carbon or EC) and on a steady-state (SS) driving cycle at

20 percent and 1 percent DPF bypass (PM dominated by sulfate). The gravimetric PM PEMS was compared against the UC-Riverside Mobile Emissions Laboratory (MEL) — a full CVS gravimetric method — and against a Dekati DMM — a real-time instrument that quantifies PM mass. Results show that:

- Partial flow brake specific PM emissions for Version 1 of the PM PEMS were higher than the MEL and DMM for all three test categories ranging from 12 to 17 percent.
- Many of the tests on Version 1.1 did not meet the proportionally requirements due to an issue with flow meter drift which affected the dilution ratio, the real-time proportionality, and the total mass calculation.

Version 2a

Version 2a of the system featuring improved flow measurement was evaluated and found to be more accurate, stable, and responsive than Version 1.1. This version also included the automatic filter indexer. A total of nine valid tests covered a range of conditions including arterial driving, freeway cruising, congested freeway operation, and cruising with grade at four DPF bypass levels ranging from 20 percent to 1 percent.

- Results showed that for all tests, the flow corrected brake specific PM relative error ranged from -1 percent to -14 percent with an R^2 of 0.999 and a slope of 0.89 for brake-specific PM emission factors ranging from 2 mg/hp-h to 45 mg/hp-h.
- The proportionality results suggested proper PM sampling flows and that a good correlation should be expected between the two gravimetric systems.
- However, some of the tests occurring during passive regenerations showed large biases. These events may have been dominated by sulfur compounds formed during regeneration. One possible cause of the bias observed during high passive regeneration events could be the 6 feet of flexible silicon conductive tubing used to transfer the sample from the exhaust to the probe for PM PEMS. The MEL uses a conductive stainless steel transfer tube to direct the vehicle's exhaust about 10 feet to the constant volume dilution tunnel. Silicon conductive tubing may be preventing the sulfuric acid particles from reaching the Teflon filter due to the tubing’s capability for water uptake and gas phases interferences.

Version 2b

Version 2a was subsequently tested on a chassis dynamometer on UDDS cycle with no CRT (4 valid tests) on two different loads (soot dominated PM). Version 2b was tested on the chassis dynamometer on UDDS cycle and on transient/SS cycle at 10 percent bypass with sulfate based PM (4 valid tests). Version 2b utilized all the components of Version 2a except the conductive tubing was replaced by stainless steel tubing for tests with CRT DPF inline. The emissions during these tests varied from 129.7 mg/bhp-hr to 3.6 mg/bhp-hr with non-CRT configuration producing emissions above 100 mg/bhp-hr while with the CRT inline, the emissions were below 50 mg/bhp-hr. Results show that for all eight valid tests, a slope of 1.01 for brake-specific PM emission was observed with R^2 of 0.9998 between MEL and gravimetric PM PEMS. All tests were within ±5 percent of MEL irrespective of the emissions rate.

III. STAFF COMMENTS

The development of gravimetric PM PEMS provided valuable new information during the course of the project. The chassis dynamometer testing showed that accurate and responsive flow measurements are critical for accurate determination of proportionality and mass loadings. The flow meter of a prominent manufacturer failed to achieve tight drift requirements and resulted in poor proportionality. The conductive tubing routinely employed by PEMS manufacturers and users was verified to work well for soot dominated exhaust PM, but may have contributed to a bias observed for exhaust PM dominated by sulfur or organic compounds.

The final version of the gravimetric PM PEMS tested against CVS reference method for soot and organic/sulfated PM dominated sources showed good correlation using conductive and stainless steel transfer lines respectively. However, additional testing of the transfer line is recommended to characterize the impact of this widely used line on measurement of PM mass emissions from modes of operation low in soot.

IV. STAFF RECOMMENDATION

Staff recommends that 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.: III.5
DATE: January 30, 2015
CONTRACT NO.: 09-318
Link to Report

STAFF EVALUATION OF A DRAFT FINAL REPORT

TITLE:	Determination of the Spatial Distribution of Ozone Precursor and Greenhouse Gas Concentrations and Emissions in the Los Angeles Basin
CONTRACTOR:	University of California, Los Angeles
PRINCIPAL INVESTIGATORS:	Jochen Stutz, Ph.D. Qinbin Li, Ph.D. Stan Sander, Ph.D.
CONTRACT TYPE:	Interagency Agreement
TOTAL AMOUNT:	$299,968
CONTRACT TERM:	58 months

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

I. SUMMARY

This project developed and deployed for three years two novel remote sensing methods from a mountaintop overlooking the South Coast Air Basin (SoCAB) to measure concentrations of several ozone precursors and greenhouse gases. The instruments, one operating in the ultraviolet-visible (UV-vis) range and the other in the near-infrared (IR), were located at the Jet Propulsion Laboratory's (JPL) Mt. Wilson California Laboratory for Atmospheric Remote Sensing (CLARS), which is located 1674 m above sea level. The UV-vis instrument is based on Multi-Axis Differential Optical Absorption Spectroscopy (MAX-DOAS) and measured solar absorption spectra of nitrogen dioxide (NO_2), formaldehyde (HCHO) and tetra oxygen ($O_{4)}$ (as a proxy for aerosol extinction) over eight elevation angles. These measurements provided height resolved concentrations and three-year time series of NO_2 and NOx/VOC sensitivity studies in the SoCAB. The near-IR instrument is based on a novel remote sensing approach - Fourier transform spectroscopy - for monitoring the spatial and temporal distributions of

greenhouse gases in the Los Angeles. The instrument recorded reflected near-IR solar radiation from a number of ground target locations in the Los Angeles basin; column-averaged dry-air mole fractions of greenhouse gases (XGHG) including XCO_2, XCH_4, and XCO were retrieved several times per day for each target. Data for each trace gas observed span three years and can be used to improve emission inventories and air quality models, and help ARB to strategically target mitigation efforts for air quality and climate change.

II. TECHNICAL SUMMARY

Objective

The primary objective the research was to develop remote sensing methods to measure three-dimensional concentrations of NO_2, HCHO, glyoxal, SO_2, O_4, and the GHGs CO, CO_2, CH_4, and N_2O over the SoCAB. Long-term measurements from these instruments will be combined with new inverse modeling methods to describe spatio-temporal patterns of air pollutants and GHGs in the SoCAB.

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Background

In California, the foundation of air quality monitoring rests on a network of ground-based sites. Locations for these sites were determined mainly to approximate average human exposures to air pollutants, and are ill-suited to monitor large air volumes for trace GHG concentrations and emissions. To address that problem, remote sensing methods that scan large areas offer the best available technology.

Project Summary

This project developed and operated two novel remote sensing instruments, one measuring in the UV-visible wavelength range and the other in the near-IR wavelength range, from a mountaintop that overlooks the SoCAB for three years. The UV-vis system is based on MAX-DOAS and measures narrow-band absorptions of the pollutants NO_2, HCHO, glyoxal, SO_2 and aerosol extinction. The instrument samples eight consecutive elevation angles in five azimuth directions from CLARS. Several tools were developed to analyze and interpret the data set of over one million measurements. A cloud sorting algorithm was developed to identify measurements that are impacted by clouds above or below Mt. Wilson; a fast radiative transfer model (RTM) that allows for the simulation of the effective light path through the atmosphere was implemented to

convert the trace gas slant column densities into concentrations and aerosol extinction vertical profiles. The RTM was combined with a two-stage non-linear / linear optimal estimation inversion to derive aerosol extinction profiles followed by the determination of trace gas profiles. The near-IR system utilizes a new Fourier transform spectrometer (CLARS-FTS) that measures reflected sunlight with high spectral resolution in the near-infrared region from 28 targets within the SoCAB. It retrieves the greenhouse gas species CO_2, CH_4, and CO. A modified version of the GFIT program, which consists of a radiative transfer (RT) model coupled to a model of the solar spectrum to calculate the spectrum of light that originates from the sun, passes through the atmosphere, and reflects from the Earth's surface, was used to derive slant column abundances of atmospheric trace gases from the measured absorption spectra.

Key results and findings from this project include:

- Time series of VOC/NOx sensitivity of ozone formation in the LA basin were explored using the HCHO/ NO_2 ratio. Calibration of this ratio with ground site measurements determined a crossover point between VOC and NO_X limited ozone formation regimes. A clear weekly pattern was found, with decrease VOC sensitivity during weekends and higher VOC sensitivity during weekdays. However, the ozone sensitivity regime does not appear to be changing substantially over the years monitored (likely due to a decrease in HCHO or VOCs accompanying the NO_2 decrease).
- Strong diurnal variations of XCO_2 and XCH_4 were observed, with typically minimum in the early morning (405-410 ppm for XCO_2 and 1900-1900 ppb for XCH_4) and a maximum at noon or early afternoon (variations of 10-30 ppm for XCO_2 and 100-200 ppb for XCH_4).
- Using ratio analysis (correlations with CO_2), results from CLARS-FTS observations indicate that CH_4 emission inventory for Los Angeles in 2011 – 2013 is 37 percent above the bottom up inventory.
- Seasonal maps of correlation slopes of XCH_4 excess to XCO_2 excess for the Los Angeles basin were determined for Sept. 2011 – Oct. 2013.

A version of WRF-Chem model for the Los Angeles Basin was developed and run to simulate the CalNex period; its results were compared to observations to gain information on the emission inventories of CO and NO_X. The model overestimated CO, both at the surface and across the basin (using a 28 percent reduction from NEI'05). The model was not able to reproduce the significant weekend to weekday differences in O_3 and NO_Y; the likely cause is that the emission inventory's weekend NO_X emissions are too high.

III. STAFF COMMENTS

Staff, from the Air Quality Planning and Science and Research Divisions, reviewed this Report and is satisfied with the presentation, synthesis, and analysis of measurements.

Staff request that further details be provided for several areas; these will be addressed by the PIs in a revised final report. The most important of these include the omission of glyoxal, SO_2, and N_20 measurements; relationship between the crossover value for $HCHO/NO_2$ and published indicators; and recent work on the inverse 3D urban air-shed models and their use in interpretation of data. In addition, staff are working with the PIs on the possibility of an addendum that contains further work on WRF-Chem adjoint and inverse modeling estimates of emission rates, additional graphics containing spatial distributions of species, and recent work on calibration of XCO_2, XCH_4, and XCO retrievals using aircraft in-situ profiles. As a final note, an entire data-set with all measured species will be provided to the ARB in electronic form at the end of the project.

In summary, the research developed new remote sensing methods on a unique observational platform - Mt. Wilson - to measure three-dimensional concentrations and emissions of air pollutants and GHGs in the SoCAB. Costs involved with equipment siting and operation were minimized by the use of an existing site (CLARS) and automated remote operation of instruments. The observations will help improve the GHG emission and ozone precursor inventories and expand the range of possible monitoring stations.

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.: III.6
DATE: January 30, 2015
CONTRACT NO.: 11-307
Link to Report

STAFF EVALUATION OF A DRAFT FINAL REPORT

TITLE:	Assessment of the Emissions and Energy Impacts of Biomass and Biogas Use in California
CONTRACTOR:	University of California, Irvine
SUBCONTRACTOR:	University of California, Davis
PRINCIPAL INVESTIGATOR:	Donald Dabdub, Ph.D.
CONTRACT TYPE:	Interagency Agreement
TOTAL AMOUNT:	$169,997
CONTRACT TERM:	24 months

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

I. SUMMARY

California has been adopting regulations to promote renewable electric power and transportation fuels through the PUC's Renewable Portfolio Standard (RPS) and the ARB's Low Carbon Fuel Standard (LCFS). Increased use of biomass and biogas for fuel and electric power can lead to reduced emissions of criteria pollutants and greenhouse gases (GHG), and thereby help achieve these standards. This study was designed to evaluate the potential air quality co-benefits of biomass and biogas use. Various feedstocks and technologies were reviewed to determine existing and projected bioenergy capacity and emissions, and air quality modeling was used to determine overall air quality impacts. With current technology and maximum power production potential, NO_X emissions could triple from current levels by 2020, leading to a 6 ppb increase in ozone concentrations downwind of major facilities. However, technology upgrades would significantly reduce these emissions. CNG production for vehicles may be the best option, in terms of air quality and GHG emissions. By providing a scientific

basis to evaluate the potential air quality co-benefits of biomass and biogas use, the results will help State agencies develop strategies to meet the RPS & LCFS.

II. TECHNICAL SUMMARY

Objective

The objectives were to analyze biomass and biogas resources and their integration into local fuel infrastructure in urban and rural/agricultural environments, to determine the associated emissions of greenhouse gases and criteria pollutants, and to evaluate the potential air quality co-benefits of biomass and biogas use. Specific objectives included:

1. Analysis of biomass and biogas resources, and prediction of their integration into urban and rural environments
2. Determination of resulting GHG and criteria pollutant emissions
3. Determination of resulting air quality impacts

Background

Biomass and biogas resources have the potential to provide a significant portion of California's energy requirements, while reducing greenhouse gas emissions and addressing air quality and waste disposal issues. Most biogas energy has been derived from digester gas and landfill gas, and most biomass energy from forest residue. However, additional sources are increasingly being used to generate electricity and renewable fuels: municipal solid waste, dairy waste, food processing waste, and gasification of sludge from wastewater processing. Biogas (from waste digestion and gasification) adds net energy benefits because waste removal and disposal costs are averted. Using biomass and biogas for energy reduces the need for conventional fuel and contributes to energy sustainability, while reducing emissions of GHG and criteria pollutants. The impact of implementation of California's 2011 Bioenergy Action Plan on GHG emissions and air quality needs to be determined.

Project Summary

This study evaluated the potential and constraints of electricity and vehicle fuel (hydrogen, biogas) supply, based on renewable bio-resources, especially in the South Coast Air Basin and the San Joaquin Valley (SJV). The report includes four tasks:

Biomass Resources, Uses of Biomass, Biomass Scenarios, and Air Quality Modeling.

Task 1: Biomass Resources

The California Biomass Collaborative (CBC, subcontractor, at the University of California, Davis) developed data on the state's biomass and biogas resources and facilities. Currently, biomass contributes 2 percent of California's power – mostly from forest waste, but also from landfill gas and wastewater treatment. In-state 'technically' recoverable biomass could provide three times as much as currently. The following current sources could be expanded significantly: anaerobic digestion of food and green waste and food processor waste; upgraded biogas for use in CNG vehicles (may also be used in fuel cells to produce electricity and hydrogen for vehicle fuel); digestion of forest residues, crop residues and used oils to produce biodiesel and ethanol; and landfill gas to fuel trucks and provide off-site process heating.

Task 2: Uses of Biomass

The University of California Irvine (UCI) evaluated the potential hydrogen and biogas generation capacity for electricity and vehicle fuel supply, based on renewable bio-resources as provided by CBC. These include wastewater treatment and landfill gas, green waste, and agricultural and dairy waste. After evaluating facilities that burn biogas, and facilities that reform biogas for other uses, UCI analyzed the resulting infrastructure to predict emissions outputs and resource consumption for several biomass and biogas technology deployments. GIS tools were used to determine plausible infrastructure deployment, including optimal location of large co-digestion plants and small distributed biomass plants. Scenarios favoring the direct use of biogas were developed and evaluated, including injecting gas into the natural gas transmission system. Assuming maximum potential biopower production, NO_X emissions from current facilities could increase from 45 to 157 tons/day in 2020; PM emissions from 5 to 17 tons/day; and CO_2 equivalent emissions from 37,000 to 151,700 tons/day or nearly 3 percent in total in-state CO_2 equivalent emissions to 9.2 percent in 2020.

Task 3: Biomass Scenarios

To determine resulting benefits in energy use and GHG emissions, UCI's Preferred Combination Assessment (PCA) model was used to integrate the biomass and biogas technology combinations and their emission factors into infrastructure scenarios on a

life-cycle basis. This included GHG analyses that considered resource availability and type of feedstock. To obtain emission factors for biomass and biogas technologies, ARB certification process information was combined with data from the CBC.

Task 4: Air Quality Modeling

Emission factors, combined with geospatially-resolved bioenergy facility locations, were used to generate new emission source locations and magnitudes. These were input to the Community Multiscale Air Quality (CMAQ) model to predict temporal air quality impacts (regional and statewide) from the biopower scenarios. Besides the base-case (no biomass) scenario, three scenarios were simulated:

1) Maximum potential for biopower production with current technology (business-as-usual): Near biopower facilities and downwind areas, ozone concentrations could increase >6 ppb. In SJV, PM2.5 concentrations could increase >2 mg/m^3.

2) Maximum potential for biopower production with technology upgrade: the increase in emissions from additional production was offset by decreases in the emissions from existing plants. The result is only minor changes in ozone and PM2.5 concentrations.

3) Maximum production of CNG from biomass for vehicle consumption: This showed a significant reduction in emissions from current biomass facilities due to CNG production and displacement of VOC emissions from gasoline marketing. Near some biopower plants, ozone concentrations could be reduced ~4 pbb, and PM2.5 concentrations could be reduced ~1 ppb.

In short, if all technically recoverable biomass resources were utilized, 4.66 GW power could be installed. Assuming current technology, this would significantly increase ozone and PM, especially in the SJV; however, technology upgrades would significantly reduce these emissions. To minimize emissions (including GHG), CNG production for vehicles may be the best option for biomass use.

III. STAFF COMMENTS

The draft final report was reviewed by ARB staff from the Air Quality Planning and Science, Industrial Strategies, and Research Divisions, and by staff from the California Energy Commission (CEC) and CalRecycle. Overall, the report was well-written; a marked-up copy with editorial suggestions was sent to the PI, who accepted them. Staff

believes this report provides a consistent analysis of air quality impacts and GHG emissions for scenarios involving increased biomass use. The findings will help industry and regulators determine optimal choices to be made as biomass and bioenergy technology is developed in California.

Following are staff comments on the draft final report, provided to the Principal Investigator, who has agreed to address them in the final report:

- Can the renewable portfolio standard (RPS) be met in all scenarios while still reaching air quality standards? Can the RPS and air quality standards only be achieved with investment in low emission technology?
- The conclusion states that biopower could increase NO_X emissions by 10 percent in 2020; quantification should be provided for other pollutant impacts. The conclusion section should also summarize future research needs.
- Maps: Air district boundaries should be added. A map for NO_X impact should be added, similar to the maps for ozone and PM2.5 impacts. Section 5.3.2 should clarify the impacts of the four scenarios from the maps. Tables should be added to show emissions by air district.
- Figures 18 & 23 show that processing agricultural waste and municipal solid waste can decrease GHG emissions. Emissions should be quantified, and distinguished between in-state and out-of-state.
- The study used California's Greenhouse gases, Regulated Emissions and Energy in Transportation (CAGreet) model, version 1.8b; how might the results differ with use of the latest version, CAGreet 2.0?
- Section 4.2.4 discusses GWPs of GHGs, and references IPCC Assessment Report 4 (AR4) numbers; how might the results differ with use of AR5 (the latest version)?

The report should discuss the likelihood of a maximum CNG-utilization scenario with enhanced technology.

IV. STAFF RECOMMENDATION

Staff recommends that 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.